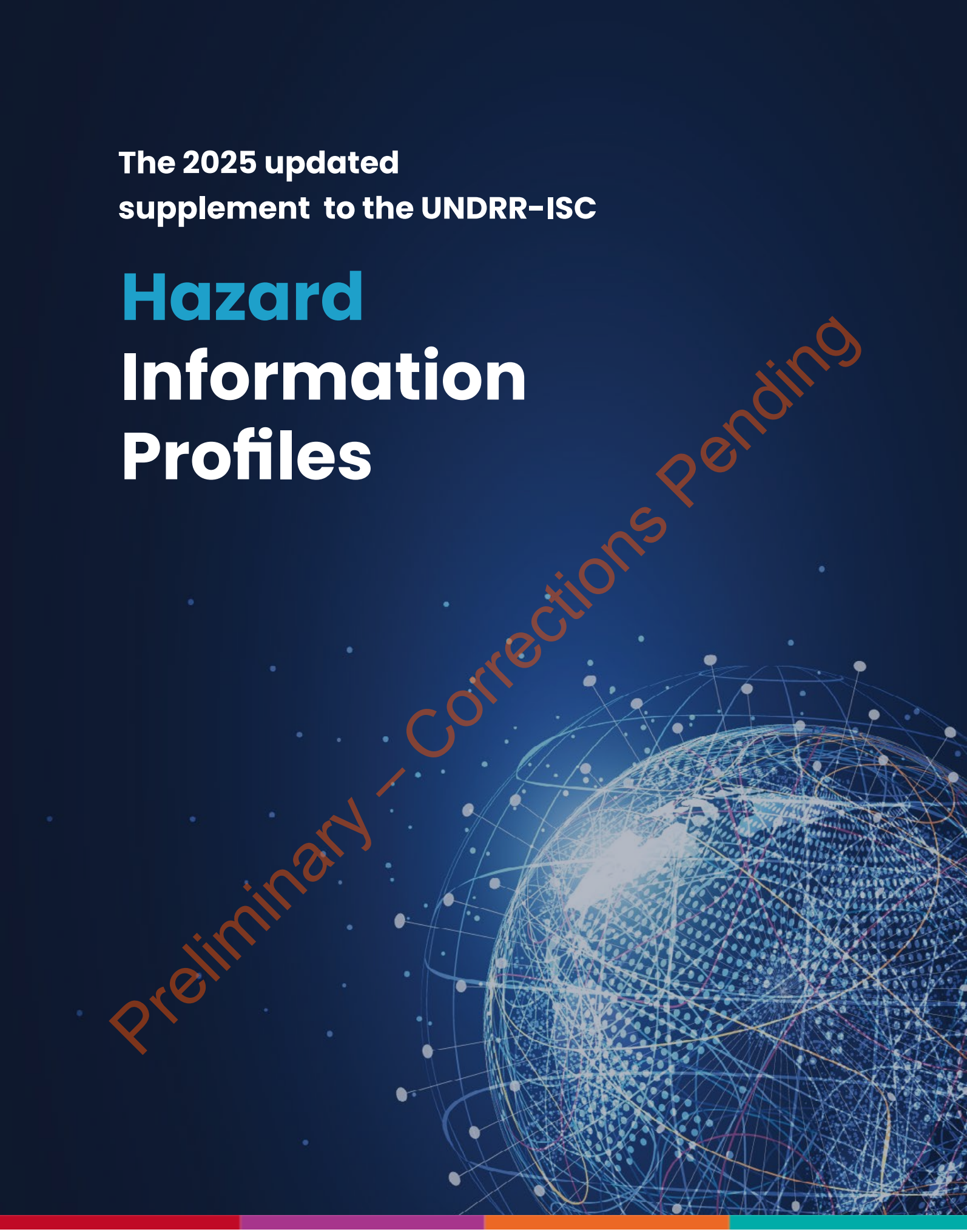
The 2025 updated supplement to the UNDRR-ISC

Hazard Information Profiles

Preliminary – Corrections Pending



SENDAI FRAMEWORK FOR DISASTER RISK REDUCTION 2015-2030

International Science Council

UNDRR UN Office for Disaster Risk Reduction

Preliminary – Corrections Pending

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METEOROLOGICAL AND HYDROLOGICAL

Preliminary – Corrections Pending

MH0101 / METEOROLOGICAL AND HYDROLOGICAL / Convective-related

Downburst

Definition

A downburst is a violent and damaging downdraught reaching the ground surface, associated with a severe thunderstorm (WMO, 1992).

Reference

WMO, 1992. International Meteorological Vocabulary. WMO-No. 182, 2nd edition. World Meteorological Organization (WMO). https://library.wmo.int/records/item/35809-international-meteorological-vocabulary?offset=2 Accessed 15 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Microburst, Macroburst, Wind Shear.

Additional scientific description

A downburst is a strong downdraft that induces an outburst of damaging winds at or near the ground. Downbursts are classified based on the horizontal extent of their outflow:

- Microburst: Affecting areas less than 4 kilometres in diameter.
- Macroburst: Covering areas greater than 4 kilometres in diameter.

Wind speeds within downbursts can reach up to 67 metres per second (approximately 240 kilometres per hour). These events typically last between 5 to 30 minutes and can cause significant damage comparable to that of tornadoes. Downbursts pose particular hazards to aviation due to the rapid changes in wind speed and direction they can induce (National Oceanic and Atmospheric Administration [NOAA], 2023).

Metrics and numeric limits

Comparison of a microburst and the larger macroburst (NOAA, 2019):

Microburst	Macroburst
Damaging winds extending up to 2.5 miles (4 km)	Damaging winds extending more than 2.5 miles (4 km)
Lasts 5 to 15 minutes	Lasts 5 to 30 minutes
Can cause damaging winds up to 168 mph (270 kp/h)	Damaging winds, causing widespread, tornado-like damage, up to 134 mph (216 kp/h)

Key relevant UN convention / multilateral treaty

Not applicable.

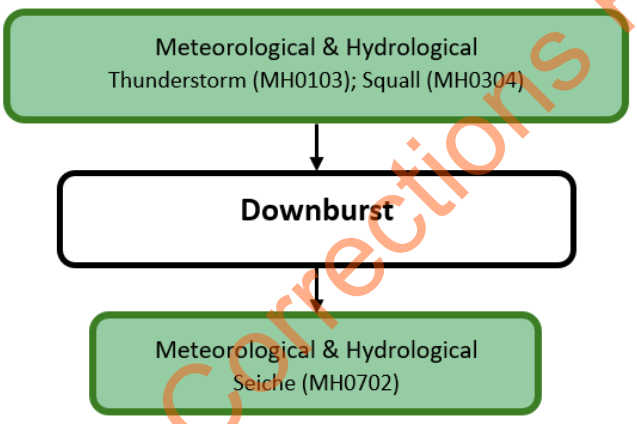
Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Downbursts are powerful, localized columns of sinking air that rapidly descend from thunderstorms and impact the ground with intense winds, often exceeding 100 km/h. A combination of evaporative cooling and precipitation drag within the storm primarily drives these hazardous wind events. As rain or hail falls through a dry or cooler layer of air below the thunderstorm, it evaporates or melts, cooling the air and making it denser. This denser air plunges downward rapidly, accelerating under gravity. When this downdraft hits the surface, it spreads out radially, generating damaging straight-line winds that can flatten trees, overturn vehicles, and pose serious risks to aviation. Strong temperature gradients and high atmospheric instability can further intensify downbursts. While often confused with tornadoes due to their destructive nature, downbursts produce different wind patterns and are classified as non-rotational. Understanding the atmospheric conditions that lead to

downbursts is critical for public safety and aviation operations. (National Weather Service [NWS], 2023).

Impacts: Downbursts are a particular hazard to aircraft at low level, especially on take off or landing. An aircraft approaching a downburst will first encounter a strong headwind, which will lead to an increase in indicated airspeed. When trying to fly a set airspeed on approach, a pilot might therefore be tempted to reduce power. This would be very dangerous because, as the aircraft passes through the downburst, the wind becomes a tailwind and the indicated airspeed and lift drop. The significant downward force of air in the downburst may be enough to force the aircraft into the ground or at least cause it to lose a significant amount of height. The subsequent loss of performance, as the aircraft encounters tailwinds, may cause further loss of height and be enough to cause the aircraft to stall (SKYbrary, no date). One of the most notable downburst-related aviation accidents occurred in 1985, when Delta Air Lines Flight 191 crashed while attempting to land at Dallas/Fort Worth International Airport, killing 137 people after encountering a powerful microburst (National Weather Service [NWS], no date). Internationally, the 1974 crash of Martinair Flight 138 in Sri Lanka, which resulted in 191 fatalities, was also linked to wind shear and downburst conditions during approach (Department of Civil Aviation, 1975). These tragedies spurred global advancements in wind shear detection systems and pilot training for weather-related hazards.

Multi-hazard Context: The figure below summarises common interactions between downbursts and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section above and the table below offer an overview of monitoring downbursts. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• Meteorological services tracking thunderstorms, wind shear, and atmospheric conditions to detect and forecast downbursts. • Aviation authorities monitoring wind hazards to ensure flight safety and issue alerts for airports and pilots. • Health authorities evaluating risks to public safety, including structural damage and injuries caused by extreme winds. • Engineers designing wind-resistant infrastructure and assessing damage from high-impact winds. • Researchers and academics, including meteorologists and climatologists, studying downburst dynamics, predictive models, and climate influences on severe wind events.
How is the Hazard Observed/Monitored/Forecast?	Downbursts are monitored using Doppler radar, which detects rapid changes in wind speed and direction, and surface weather stations that measure sudden pressure drops and temperature shifts. Meteorologists observe storm structures, especially strong thunderstorms, to identify conditions favourable for downbursts, such as intense rainfall and evaporative cooling. Forecasting downbursts is challenging due to their sudden nature, but advanced models and real-time radar data help predict their likelihood, allowing for warnings to protect aviation, infrastructure, and communities from dangerous wind impacts.

Risk Management: Many lives have been saved because of the reduction, if not elimination, of potential airline crashes caused by dangerous wind shear conditions on take-off and landing. These saved lives are the result of training pilots on the dangers of microbursts and the installation of Doppler radars at major airports across the United States to warn pilots when microbursts are present (Wilson and Wakimoto, 2001).

Preliminary – Corrections Pending

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Coordinating agency or organisation

World Meteorological Organization (WMO).

Preliminary – Corrections Pending

MH0102 / METEOROLOGICAL AND HYDROLOGICAL / Convective-related

Lightning (Electrical Storm)

Definition

Lightning is the luminous manifestation accompanying a sudden electrical discharge that takes place from or inside a cloud or, less often, from high structures on the ground or from mountains (WMO, 2017).

Reference

WMO, 2017. International Cloud Atlas: Lightning. World Meteorological Organization (WMO). https://cloudatlas.wmo.int/lightning.html Accessed 15 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Bolt, Thunderbolt, Bolt-from-the-blue, Firebolt, Thunderstroke, Thunderball.

Additional scientific description

Lightning is a transient, high-current electric discharge with path lengths measured in kilometres. The most common source of lightning is the electric charge separated in ordinary thunderstorm clouds. Well over half of all lightning discharges occur within the thunderstorm cloud and are called intracloud discharges (AMS, 2012).

Lightning is a large electrical discharge caused by a thundercloud. It can occur within a cloud as intracloud lightning, between clouds as intercloud lightning, or between the cloud and the earth as cloud-to-ground lightning. A lightning discharge consists of pulses of electric current carried by electrons. The current is driven by a high voltage between the cloud's charge centres or between them and the earth. During the development of a thundercloud, negative charge is accumulated in the hail-forming region at the central part of the cloud, and positive charge in the top region, which consists of ice crystals (Finnish Meteorological Institute, 2019).

Lightning strikes are classified into different types according to their own characteristics. The two most common types are cloud-to-ground lightning and cloud-to-cloud lightning (WMO, 2017).

- *Cloud-to-ground lightning* is a lightning discharge between a cumulonimbus cloud and the ground. Of all types of lightning, cloud-to-ground lightning poses the greatest threat to people and facilities on the ground (WMO, 2017). The usual cloud-to-ground lightning has been studied more extensively than other lightning forms because of its practical interest (i.e., as a cause of injury and death, disturbances in power and communication systems, and ignition of forest fires) and because lightning channels below cloud level are more easily photographed and studied with optical instruments (AMS, 2012). Cloud-to-ground lightning can occur as either positively or negatively charged bolts. Positively charged bolts are considerably rare, more powerful (e.g., by an order of magnitude or more), and often can strike miles beyond the parent anvil of the thunderstorm (e.g., these positive strikes are referred to as a 'bolt out of the blue') (NOAA, 2019).
- *Cloud-to-cloud lightning* and cloud-to-air discharges are less common than intracloud or cloud-to-ground lightning. All discharges other than cloud-to-ground are often lumped together and called cloud discharges (AMS, 2012; WMO, 2017). Cloud-to-cloud lightning is the discharge between areas of the cloud without the discharge channel reaching the ground. Most of the time, it occurs between oppositely charged portions of the same cloud, but sometimes, it takes place between two separate clouds. Since the discharge channel of cloud-to-cloud lightning may be obscured by the cloud, it may or may not be visible to an observer on the ground. It may, therefore, be surprising to learn that cloud-to-cloud lightning is, in fact, the most frequently occurring type of lightning. It occurs around ten times more often than cloud-to-ground lightning. Cloud-to-cloud lightning does not threaten life and property on the ground. However, this type of lightning occurs in the sky and sometimes passes through the clear air between clouds; therefore, it is of great practical interest to those concerned with the safety of aircraft (WMO, 2017).

Ball lightning includes a fireball that sometimes appears after a lightning flash. Its diameter is usually between 10 and 20 cm and rarely attains 1 m. The fireball moves slowly through the air or along the ground and may be distorted in passing through narrow places and usually vanishes suddenly with a violent explosion (WMO, 1992).

Metrics and numeric limits

Lightning is a transient, high-current electric discharge in the atmosphere, typically occurring during thunderstorms. It results from the separation of electric charges within clouds, leading to a rapid release of electrical energy.

Key Characteristics:

- Voltage: A typical lightning flash involves a potential difference of about 300 million volts (NOAA, 2024).
- Current: The peak current of a lightning discharge is approximately 30,000 amperes (NOAA, 2024).
- Temperature: The temperature within the lightning channel can reach up to 30,000 °C (54,000 °F) (Met Office, 2024).
- Speed: The return stroke of lightning travels at about one-third the speed of light, which is approximately 100,000 km/s (62,000 miles per second) (Britannica, 2024).
- Duration: A typical lightning flash lasts about 0.2 seconds, comprising multiple strokes, each lasting a few milliseconds (Britannica, 2024).

Lightning poses significant hazards, including fires, structural damage, and risks to life. Its high temperatures can ignite materials, and the immense electrical energy can cause severe injuries or fatalities to living beings.

Key relevant UN convention / multilateral treaty

Not available.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: No Information Available

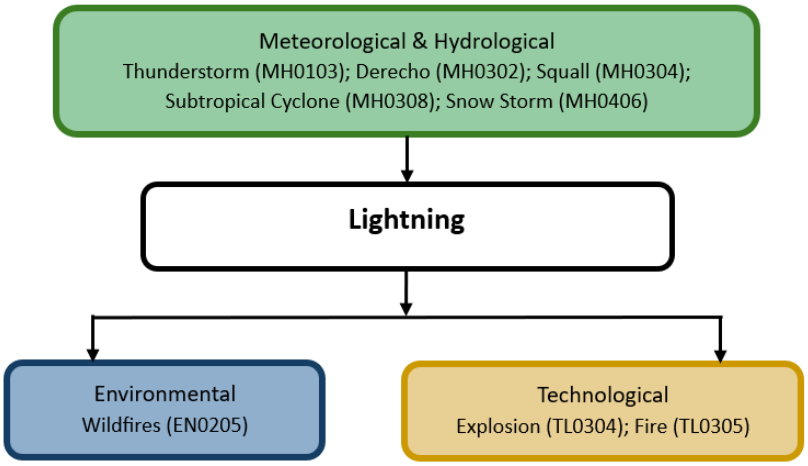
Impacts: Lightning strikes the earth more than 8 million times per day. The risk of being struck is low, but the consequences of lightning strike injuries are serious. During 2003-2012, lightning caused an average of 35 deaths per year in the United States (CDC, no date).

Lightning strikes alone cause numerous fatalities and injuries each year. According to the National Weather Service (NWS), an average of 20-30 people die annually in the United States due to lightning strikes, with many more suffering severe injuries (NOAA, 2023).

Lightning affects various sectors including electricity generation, transmission, and distribution; forestry; agriculture; telecommunications; transportation; and tourism and recreation (Mills et al., 2009). Lightning can ignite wildfires and damage electrical grids, resulting in power outages that may last for days (Alpay et al., 2020). In Canada, for example, annual lightning-related damage and disruption costs have previously been estimated between CA$600 million to CA$1 billion, with forestry and electricity damages accounting for over 85% of the total (Mills et al., 2009).

More recent studies have also demonstrated the significant lightning-related risks to the forestry sector. Studies of the extratropical forests have shown increasing risks to these forests due to lightning fires. The extratropical forests have experienced high fire-related losses, which in turn also carry long-term climate-related implications due to extratropical forests being of global importance for carbon storage (Janssen et al., 2023).

Multi-hazard Context: The figure below summarises common interactions between lightning and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section above and the table below offer an overview of monitoring lightning. This information can be used for

Preliminary – Corrections Pending

forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• Meteorological service that tracks thunderstorms, detect lightning strikes using ground-based networks and satellites, and issue early warnings. • Aviation authorities monitoring lightning activity to ensure flight safety and issue alerts for pilots and airports. • Health authorities assessing public safety risks, including lightning-related injuries, fatalities, and health system preparedness. • Engineers developing lightning protection systems for buildings, power grids, and critical infrastructure. • Energy and utility companies monitoring lightning threats to power transmission networks and mitigating outage risks. • Land use and urban planners incorporating lightning risk assessments into building regulations and safety standards. • Researchers and academics, including atmospheric scientists, studying lightning dynamics, forecasting techniques, and climate impacts on lightning frequency.
How is the Hazard Observed/Monitored/Forecast?	Lightning is monitored using ground-based detection networks, weather satellites, and Doppler radar (which can observe conditions conducive to lightning forecasting). Ground-based detection networks can detect lightning strikes in real-time, providing location, intensity, and frequency data. Meteorologists use this information to include the risk of lightning strikes within their thunderstorm forecasts, advisories, and warnings. Advancements in lightning research and weather modelling help improve predictions, reducing risks for aviation, outdoor activities, and infrastructure.

Risk Management: To reduce the risk of lightning-related injuries, individuals should seek shelter indoors or in a fully enclosed vehicle during thunderstorms and avoid open fields, tall trees, and bodies of water (CDC, 2023). Governmental authorities can mitigate exposure by implementing early warning systems, closing outdoor venues during lightning threats, and educating communities on lightning safety protocols (NOAA, 2023). Structurally, buildings and critical infrastructure should be equipped with lightning protection systems, including air terminals, grounding conductors, and surge protection devices, as outlined in the NFPA 780 standard (NFPA, 2024). These combined measures significantly lower lightning-related casualties and damage.

The Centres for Disease Control and Prevention also provides helpful fact sheets on lightning safety tips, first aid recommendations, lightning strike victim data, information for workers, information for outdoor recreation, information for organised sporting events, information for water activities, and information for pet owners (CDC, 2020).

As an example of a National Alerting Parameters, the China Meteorological Administration (2012) has three alerting thresholds and related preventative measures, including:

- Yellow: “In 6 hours, there will be thunder & lightning and likely to cause disasters.”
- Orange: “In 2 hours, the thunder & lightning is either occurring or will occur with a high likelihood, and it’s quite possible to cause disasters or accidents.”
- Red: “In 2 hours, the thunder & lightning is either occurring or will occur with the highest likelihood; it’s extremely possible to cause disasters or accidents.”

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World Meteorological Organization (WMO), 2017. Lightning: Cloud discharge. Available at: https://cloudatlas.wmo.int/en/lightning-cloud-discharges.html Accessed 15 May 2025.

Coordinating agency or organisation

World Meteorological Organization (WMO).

Preliminary – Corrections Pending

MH0103 / METEOROLOGICAL AND HYDROLOGICAL / Convective-related

Thunderstorm

Definition

A thunderstorm is defined as one or more sudden electrical discharges, manifested by a flash of light (lightning) and a sharp or rumbling sound (thunder) (WMO, no date).

Reference

WMO, 2017. International Cloud Atlas: Thunderstorm. World Meteorological Organization (WMO). https://cloudatlas.wmo.int/en/thunderstorm.html Accessed 15 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

None identified.

Additional scientific description

Thunderstorms are associated with cumulonimbus clouds (WMO, 2017) and are most often accompanied by precipitation that, when it reaches the ground, is in the form of a shower of rain, snow, snow pellets, small hail, or hail. Thunderstorms can cause tornadoes, strong winds, and flash flooding (Habitat for Humanity, 2021).

Metrics and numeric limits

Example types of thunderstorms (NOAA, no date a, b; Australian Government, no date):

Single-cell	Single-cell thunderstorms are small, brief, weak storms that grow and die within an hour or so. They are typically driven by heating on a summer afternoon. Single-cell storms may produce brief heavy rain and lightning.
Multi-cell	A multi-cell storm is a thunderstorm in which new updrafts form along the leading edge of rain-cooled air (the gust front). Individual cells usually last 30 to 60 minutes, while the system as a whole may last for many hours. Multicell storms may produce hail, strong winds, brief tornadoes, and/or flooding.
Squall line	A squall line is a group of storms arranged in a line, often accompanied by 'squalls' of high wind and heavy rain. Squall lines tend to pass quickly and are less prone to produce tornadoes than supercells. They can be hundreds of miles long but are typically only 10 or 20 miles wide.
Supercell	A supercell is a long-lived (greater than 1 hour) and highly organised storm feeding off an updraft (a rising current of air) that is tilted and rotating. This rotating updraft — as large as 16 kilometres (10 miles) in diameter and up to ~15,000 meters (50,000 feet) tall — can be present as much as 20 to 60 minutes before a tornado forms. Scientists call this rotation a mesocyclone when it is detected by Doppler radar. The tornado is a very small extension of this larger rotation. Most large and violent tornadoes come from supercells.
Mesoscale convective system	A mesoscale convective system (MCS) is a collection of thunderstorms that act as a system. An MCS can spread across large areas and last more than 12 hours. On radar, one of these might appear as a solid line, a broken line, or a cluster of cells.
Mesoscale convective complex	A mesoscale convective complex (MCC) – a particular type of MCS – is a large, circular, long-lived cluster of showers and thunderstorms identified by satellite. It often emerges out of other storm types during the late-night and early-morning hours.
Mesoscale convective vortex	A mesoscale convective vortex (MCV) is a low-pressure centre within an MCS that pulls winds into a circling pattern, or vortex. With a core only 30 to 60 miles wide and 1 to 3 miles deep, an MCV is often overlooked in standard weather analyses. But an MCV can take on a life of its own, persisting for up to 12 hours after its parent MCS has dissipated. This orphaned MCV will sometimes then become the seed of the next thunderstorm outbreak. An MCV that moves into tropical waters, such as the Gulf of Mexico, can serve as the nucleus for a tropical storm or hurricane.

Derecho	A derecho (pronounced similar to 'deh-REY-cho' in English) is a widespread, long-lived wind storm that is associated with a band of rapidly moving showers or thunderstorms. Although a derecho can produce destruction similar to that of tornadoes, the damage typically is directed in one direction along a relatively straight swath. As a result, the term 'straight-line wind damage' is sometimes used to describe derecho damage. By definition, if the wind damage swath extends more than 400 kilometres (~250 miles) and includes wind gusts of at least 93 km/h (58 mph) or more along most of its length, then the event may be classified as a derecho.
Virga	Thunderstorms can be considered dry if they do not produce any rain at the surface. However, for the fire weather community, a 'dry thunderstorm' may be used to describe a storm producing very little rainfall, such that it is not effective in checking fire spread after lightning ignition. The second scenario is more common, although there are rare instances when thunderstorms produce no sensible rainfall. In the purest sense, 'dry' thunderstorms produce virga, which is rain that evaporates at some point between the cloud base and the ground.

Key relevant UN convention / multilateral treaty

Not applicable.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Thunderstorms are meteorological events characterized by the presence of lightning and thunder, often accompanied by heavy rainfall, strong winds, hail, and occasionally tornadoes. They develop when three primary conditions converge: moisture in the lower atmosphere, atmospheric instability (where warm air is overlain by cooler air aloft), and a lifting mechanism such as a cold front or sea breeze that forces the warm, moist air to rise. As this air ascends, it cools and condenses, forming cumulonimbus clouds and initiating the convective processes that lead to thunderstorms. (National Weather Service [NWS], 2024)

Impacts: The impacts of thunderstorms are diverse and can be severe. Lightning strikes are a significant hazard, responsible for numerous fires and fatalities annually. Heavy rainfall can lead to flash flooding, which causes more deaths each year than hurricanes, tornadoes, or lightning. Strong winds associated with thunderstorms can damage structures, uproot trees, and pose risks to aviation. Hailstones, sometimes reaching sizes comparable to softballs, can cause substantial damage to vehicles, windows, and crops. Additionally, thunderstorms can spawn tornadoes, leading to further destruction. (National Severe Storms Laboratory [NSSL], 2024)

Thunderstorm outflow concentrates airborne allergens, such as pollen, near ground level, increasing the risk of exposure for predisposed individuals and epidemic thunderstorm asthma events contribute to an increased severity of asthmatic symptoms within sensitized populations. Although infrequent, they are a global phenomenon, with 26 known events reported worldwide and may be responsible for a large number of asthma exacerbations resulting in hospitalizations and occasionally deaths Incidents have been documented in 1994 in London UK Venables et al 1997), in 2013 in Iran, in 2016 in Saudi Arabia, and in 2016 Melbourne, Australia epidemic (Price et al 2021).

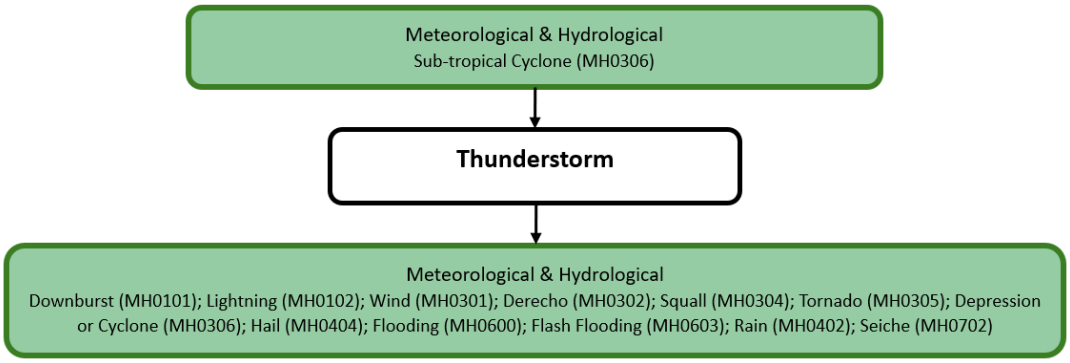
Thunderstorms can also pose direct threats to human safety. Lightning strikes alone cause numerous fatalities and injuries each year. According to the National Weather Service (NWS), an average of 20-30 people die annually in the United States due to lightning strikes, with many more suffering severe injuries (NOAA, 2023). Flash flooding, often triggered by heavy rainfall in thunderstorms, is another major hazard, leading to drowning deaths and property damage.

Severe thunderstorms can disrupt power supplies, damage buildings, and affect transportation networks. Lightning can ignite wildfires and damage electrical grids, resulting in power outages that may last for days (Alpay et al., 2020). Strong winds and hail can damage or destroy crops, negatively impacting agricultural production (Elahi et al., 2022).

Thunderstorms also pose significant risks to the transportation sector, particularly aviation, leading to delays, turbulence, low-level wind-shear and even aircraft damage (U.S. Department of Transportation, 2013). Road transportation is also affected, as strong gusts of wind, flooding and toppled trees can create dangerous driving conditions (MeteoSwiss, no date).

Multi-hazard Context: The figure below summarises common interactions between thunderstorms and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

Preliminary – Corrections Pending



Monitoring: The section above and the table below offer an overview of monitoring thunderstorms. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• Meteorological service that tracks atmospheric conditions, monitor storm development using radar and satellites, and issue thunderstorm warnings. • National, subnational, and local disaster management agencies responsible for monitoring severe weather threats and coordinating emergency responses. • Aviation authorities monitoring storm activity to ensure flight safety and provide real-time updates for pilots and air traffic control. • Health authorities assessing risks associated with thunderstorms, including lightning-related injuries, respiratory issues, and disease outbreaks from heavy rainfall. • Engineers designing storm-resistant infrastructure, improving drainage systems, and assessing wind and lightning damage. • Energy and utility companies monitoring thunderstorm threats to power grids, communication networks, and critical infrastructure. • Land use and urban planners integrating thunderstorm hazard assessments into building codes and development regulations. • Researchers and academics, including meteorologists and climate scientists, studying thunderstorm patterns, climate impacts, and forecasting improvements.
How is the Hazard Observed/Monitored/Forecast?	Thunderstorms are monitored using Doppler radar, weather satellites, and ground-based sensors that track cloud formations, wind patterns, and lightning activity. Meteorologists analyse temperature, humidity, and wind shear to predict storm development and intensity. Advanced weather models and real-time data help forecast thunderstorms and their movement, allowing for early warnings to protect aviation, infrastructure, and communities from hazards like heavy rain, strong winds, lightning, and hail.

Risk Management: Effective risk management for thunderstorms involves several strategies. Implementing early warning systems, such as monitoring weather forecasts and staying alert to severe weather advisories, is crucial. Strengthening infrastructure to withstand strong winds and ensuring proper drainage systems can mitigate damage from wind and flooding. Public education campaigns are essential to inform individuals about safety measures, such as seeking shelter during storms and avoiding contact with electrical appliances and plumbing, which can conduct electricity from lightning strikes. Developing and regularly updating emergency response plans ensures coordinated actions among emergency services and community organizations during and after storm events. (National Oceanic and Atmospheric Administration [NOAA], 2024)

A comprehensive approach toward management and prevention of ETSA includes environmental strategies, with forecasting and early warning to reduce exposure; and public health strategies, which include taking proper precautions to remain indoors, taking preventive inhaled steroids, and having ready access to inhalers (Price et al 2021).

Preliminary - Corrections Pending

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Coordinating agency or organisation

World Meteorological Organization (WMO).

Preliminary – Corrections Pending

MH0201 / METEOROLOGICAL AND HYDROLOGICAL / Particle-related

Dust storm or Sandstorm

Definition

A dust storm is an ensemble of particles of dust or sand energetically lifted to great heights by a strong and turbulent wind (WMO, 2017).

Reference

WMO, 2017. Dust Storm or Sandstorm. International Cloud Atlas, World Meteorological Organization (WMO). https://cloudatlas.wmo.int/dust-storm-or-sandstorm.html Accessed 16 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Haboob, Harmattan, Shamal.

Additional scientific description

Dust storms or sandstorms generally occur in areas where the ground is covered with loose dust or sand. Sometimes, after having travelled great distances, they may be observed over areas where no dust or sand covers the ground. The forward portion of a dust storm or sandstorm may have the appearance of a wide and high wall that advances fairly rapidly. Walls of dust or sand often accompany a cumulonimbus that may be hidden by the dust or sand particles. They may also occur without any clouds along the forward edge of an advancing cold air mass (WMO, 2017).

Metrics and numeric limits

Emissions of sand and dust particles in the air typically have a wind threshold value ranging from about 4 m/s in desert areas to close to 10 m/s in semi-arid regions. As a first approximation, and being fully aware that visibility in sandstorms and dust storms may be influenced by the optical characteristics of the aerosols (chemical composition, particle size spectra) and lighting conditions (solar azimuth, background luminance, presence of medium or high cloud), the following thresholds, which are familiar to human observers and automated systems alike, are recommended (ICAO, 2009):

VIS <3000 m visibility and gusts of ≥20 kt	'light' sandstorm or dust storm
VIS <1500 m visibility and gusts of ≥30 kt	'moderate' sandstorm or dust storm
VIS <500 m and gusts of ≥ 40 kt	'heavy' sandstorm or dust storm

Key relevant UN convention/multilateral treaty

The UN Sand and Dust Storm (SDS) Coalition includes the World Meteorological Organization, United Nations Convention to Combat Desertification, United Nations Development Programme, United Nations Environment Programme, Food and Agriculture Organization, World Health Organization, World Bank, etc. and was launched at the United Nations Convention to Combat Desertification (UNCCD) Conference of the Parties on 6 September 2019 (United Nations, 2019).

Examples of hazard drivers, impacts, and risk management

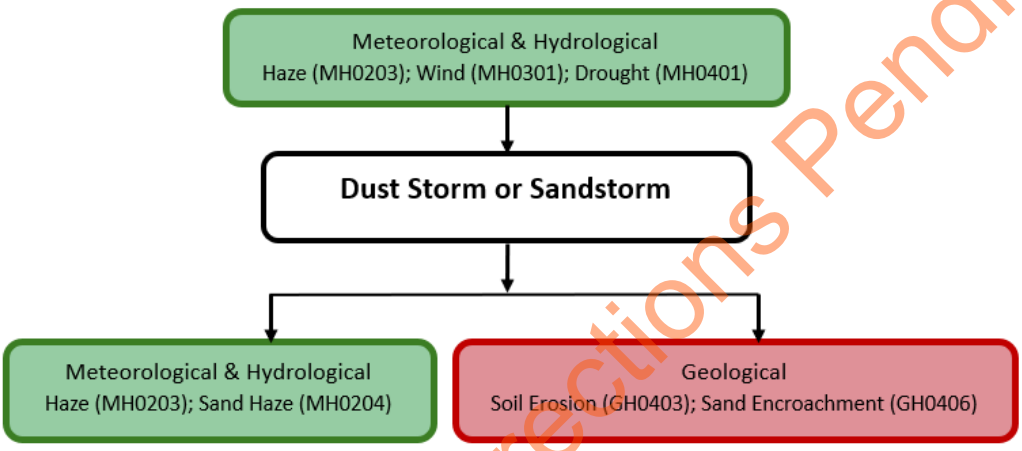
Hazard Drivers: Sand and dust storms are a meteorological hazard, which is related to the process of wind erosion of surface soil and the mineral dust aerosol emission to the atmosphere. They are frequent in northern Africa, the Middle East and Europe, the Arabian Peninsula, Central Asia, northern India, north-western China, southern Mongolia and adjacent Asian countries (WMO, 2019).

Impacts: In desert regions of Australia and the USA, they can seriously threaten human health, agriculture, aviation, ground transportation, the solar energy industry, air quality, infrastructure and industry, as well as aquatic and terrestrial ecological systems. Dust aerosol can carry irritating spores, bacteria, viruses and persistent organic pollutants. Sand and dust storms also transport nutrients to the oceans and affect marine biomass production, which in turn influences greenhouse gas emissions in the marine environment (WMO, 2019).

In terms of health impacts from dust storms and sandstorms, the UNCCD recognizes that sand and dust storms cause numerous human health problems in different regions around the world, especially in arid and semi-arid regions, and that there is a need to reinforce protective strategies to reduce the negative impacts of sand and dust storms on human health (United Nations, 2019).

Examples of national guidance on the health impacts from dust storms and sandstorms include (i) a fact sheet provided by the Australian Government on the health impacts of dust storms where exposure can produce common symptoms that include itchy or burning eyes, throat irritation, skin irritation, coughing or sneezing, and/or respiratory or breathing difficulties, including asthma attacks (Australian Capital Territory, 2018) and (ii) a guidance sheet on acute exposure and threats to respiratory health prepared by the American Thoracic Society (2018).

Multi-hazard Context: The figure below summarises common interactions between dust storms or sandstorms and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section above and the table below offer an overview of monitoring dust storms or sandstorms. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• National, subnational, and local disaster management agencies responsible for monitoring dust and sandstorm risks, issuing warnings, and coordinating emergency response. • Meteorological service tracking wind patterns, atmospheric conditions, and storm formation using weather models, satellites, and ground-based sensors. • Air quality monitoring agencies measuring airborne particulate matter (PM10, PM2.5) to assess health impacts and visibility reductions during dust and sandstorms. • Geophysical and atmospheric research institutions studying land surface conditions, desertification, and dust storm dynamics. • Health authorities evaluating public health risks, including respiratory diseases and eye irritation, and providing guidance for vulnerable populations. • Agriculture and land management agencies assessing soil erosion, desertification, and the impact of dust storms on crops and livestock. • Energy and utility companies monitoring risks to power lines, solar farms, and wind turbines from dust and sand accumulation. • Transportation and aviation authorities assessing visibility hazards for road, rail, and air travel and issuing advisories for safe operations. • Space and remote sensing agencies using satellites and LiDAR technology to monitor dust cloud movements and global distribution. • Researchers and academics, including climatologists and environmental scientists, studying dust storm frequency, climate change impacts, and mitigation strategies. • Environmental organizations and conservation groups promoting soil conservation, afforestation, and land management practices to reduce dust storm occurrences.
How is the Hazard Observed/Monitored/Forecast?	Dust storms and sandstorms are monitored using weather satellites, ground-based sensors, and LiDAR technology to track airborne dust levels, wind speeds, and visibility. Meteorologists analyse wind patterns, soil conditions, and atmospheric stability to predict when and where storms may form. Computer models simulate dust movement, helping forecasters issue early warnings. These alerts help protect public health, transportation, and infrastructure from the hazards of reduced visibility and poor air quality.

Preliminary – Corrections Pending

Risk Management: The World Meteorological Organization Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) enhances the ability of countries to deliver timely, quality sand and dust storm forecasts, observations, information, and knowledge to users through an international partnership of research and operational communities. It operates through the Global SDS-WAS Steering Committee and three regional nodes: for (i) Northern Africa, Middle East and Europe, (ii) Asia, and (iii) the Americas (Baklanov, 2018).

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Coordinating agency or organisation

World Meteorological Organization (WMO)

Preliminary – Corrections Pending

MH0202 / METEOROLOGICAL AND HYDROLOGICAL / Particle-related

Fog

Definition

Fog is a suspension of very small, usually microscopic water droplets in the air, reducing visibility at the Earth's surface (WMO, 2017).

Reference

WMO, 2017. Fog. International Cloud Atlas: World Meteorological Organization (WMO). https://cloudatlas.wmo.int/fog.html Accessed 16 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Not identified.

Additional scientific description

Under light wind, stable and humid conditions, if the air near the ground cools sufficiently, water vapour in the air may condense into tiny water droplets. These droplets reduce the visibility near ground level. This phenomenon is called fog (Hong Kong Observatory, 2019).

Fog differs from cloud only in that its base is at the Earth's surface while the cloud base is above the Earth's surface. When composed of ice crystals, it is termed ice fog (WMO, 2017). Visibility reduction in fog depends on the concentration of cloud condensation nuclei and the resulting distribution of droplet sizes. According to the American Meteorological Society (AMS) weather observing practice, fog that hides less than 0.6 of the sky is called ground fog. If fog is so shallow that it is not an obstruction to vision at a height of 6 feet above the surface, it is called simply shallow fog (AMS, 2012).

Fog is easily distinguished from haze by its higher relative humidity (near 100%, having physiologically appreciable dampness) and grey colour. Haze does not contain activated droplets larger than the critical size according to Köhler theory (AMS, 2012).

Mist may be considered an intermediate between fog and haze; its particles are smaller (a few microns maximum), it has lower relative humidity than fog, and does not obstruct visibility to the same extent (AMS, 2012).

There is no distinct line, however, between any of these categories. Near industrial areas, fog is often mixed with smoke, and this combination has been known as smog. However, fog droplets are usually absent in photochemical smog, which only contains inactivated haze droplets (AMS, 2012).

In aviation weather observations, fog is encoded F, and ground fog GF (AMS, 2012).

Metrics and numeric limits

Not identified.

Key relevant UN convention / multilateral treaty

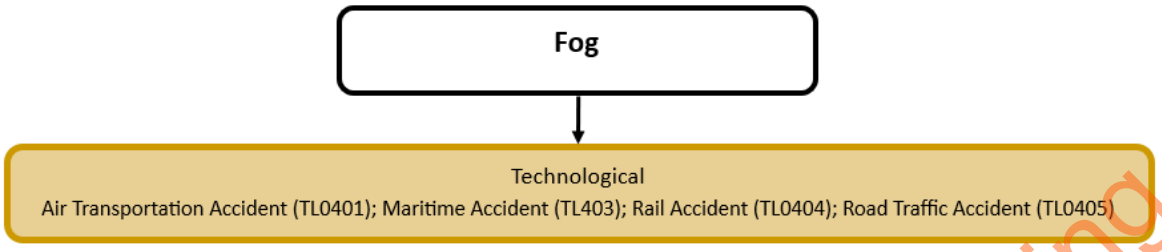
Not applicable.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Fog of all types originates when the temperature and dew point of the air become identical (or nearly so). This may occur through cooling of the air to a little beyond its dew point (producing advection fog, radiation fog, or upslope fog), or by adding moisture and thereby elevating the dew point (producing steam fog or frontal fog). Fog seldom forms when the dew point spread is greater than 4°F (-15.56°C) (AMS, 2012).

Impacts: Fog can reduce visibility both on land and on marine surfaces. By international agreement (particularly for aviation purposes), fog is the name given to the resulting visibility of less than 1 km (0.6 mile), however, in forecasts for the public, this generally refers to visibility of less than 180 m (0.1 mile) (UK Met Office, 2019).

Multi-hazard Context: The figure below summarises common interactions between fog and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section above and the table below offer an overview of monitoring fog. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• National, subnational, and local disaster management agencies responsible for monitoring fog-related risks, issuing warnings, and coordinating emergency response. • Meteorological services tracking temperature, humidity, and wind conditions that contribute to fog formation using weather stations, satellites, and models. • Air quality monitoring agencies assessing fog-related air pollution impacts, including interactions with industrial emissions and particulate matter. • Geophysical and atmospheric research institutions studying fog formation, dispersion, and long-term trends related to climate change. • Health authorities evaluating public health risks associated with reduced air quality, respiratory issues, and transportation accidents caused by dense fog. • Transportation and aviation authorities monitoring visibility conditions and issuing advisories for road, rail, and air travel to prevent accidents. • Energy and utility companies assessing risks to power transmission, wind farms, and solar energy efficiency due to fog-related moisture accumulation. • Space and remote sensing agencies using satellite and LiDAR technology to observe fog coverage and movement patterns. • Researchers and academics, including climatologists and atmospheric scientists, studying fog dynamics, microphysics, and predictive modelling improvements. • Environmental organisations and conservation groups studying fog harvesting for water conservation and its role in local ecosystems.
How is the Hazard Observed/Monitored/Forecast?	Fog is monitored using weather stations, satellites, and LiDAR technology to track temperature, humidity, and visibility conditions in real time. Meteorologists analyse these factors along with wind speed and atmospheric pressure to predict when and where fog will form. Computer models simulate fog formation and behaviour, helping forecasters issue warnings for transportation, aviation, and public safety. Early alerts help reduce accidents, improve air quality assessments, and support industries affected by low visibility.

Risk Management: In terms of national alerting parameters, examples include alerting parameters for issuing a fog advisory in Canada (Government of Canada, 2019) and alerting parameters for a heavy fog warning in China (China Meteorological Administration, 2012).

Preliminary – Corrections Pending

References

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Coordinating agency or organisation

World Meteorological Organization (WMO).

Preliminary – Corrections Pending

MH0203 / METEOROLOGICAL AND HYDROLOGICAL / Particle-related

Haze

Definition

Haze is a suspension in the air of extremely small, dry particles invisible to the naked eye and sufficiently numerous to give the air an opalescent appearance (WMO, 2017).

Reference

WMO, 2017. Haze. International Cloud Atlas, World Meteorological Organization (WMO). https://cloudatlas.wmo.int/haze.html Accessed 16 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Not available.

Additional scientific description

As light is scattered by haze particles, distant bright objects or lights seen through the haze appear yellowish or reddish, while dark objects appear bluish. Haze particles may have a colour of their own that also contributes to this effect (WMO, 2017). In addition, haze has been described as particles suspended in air, reducing visibility by scattering light; often a mixture of aerosols and photochemical smog (AMS, 2012).

Some specific types of haze include:

- *Dust haze*: A suspension in the air of dust or small sand particles raised from the ground prior to the time of observation by a dust storm or sandstorm. The dust storm or sandstorm may have occurred either at or near the observation site or far from it (WMO, 2017).
- *Sand haze*: Haze caused by the suspension in the atmosphere of small sand or dust particles raised from the ground prior to the time of observation by a sandstorm or dust storm (WMO, 1992).

Many aerosols increase in size with increasing relative humidity due to deliquescence, drastically decreasing visibility. On Köhler curve plots of saturation relative humidity versus aerosol particle radius, equilibrium haze particles are to the left of the peak, while growing cloud droplets are to the right (AMS, 2012).

Many haze formations are caused by the presence of an abundance of condensation nuclei, which may grow in size, due to a variety of causes, and become mist, fog, or cloud. Distinction is sometimes drawn between dry haze and damp haze, largely on the basis of differences in optical effects produced by the smaller particles (dry haze) and larger particles (damp haze), which develop from slow condensation upon the hygroscopic haze particles (AMS, 2012).

Dry haze particles, with diameters of the order of 0.1 micron, are small enough to scatter shorter wavelengths of light preferentially (although not according to the inverse fourth-power law of Rayleigh scattering). Such haze particles produce a bluish colour when the haze is viewed against a dark background, for dispersion allows only the slightly bluish scattered light to reach the eye. The same type of haze, when viewed against a light background, appears as a yellowish veil, for here the principal effect is the removal of the bluer components from the light originating in the distant light-coloured background (AMS, 2012).

Haze may be distinguished by this same effect from mist, which yields only a grey obscuration, since the particle sizes are too large to yield appreciable differential scattering of various wavelengths (AMS, 2012).

Metrics and numeric limits

Haze is an atmospheric phenomenon characterized by the accumulation of fine particulate matter, particularly $PM_{2.5}$ (particles with diameters less than 2.5 micrometers), which can severely reduce visibility and degrade air quality. The World Health Organization (WHO) classifies $PM_{2.5}$ as the principal pollutant used to evaluate haze-related health risks, and in its 2021 air quality guidelines, recommends that average annual $PM_{2.5}$ concentrations not exceed 5 µg/m³, with a 24-hour mean limit of

15 µg/m³ to protect public health (WHO, 2021). However, during severe haze episodes, such as those driven by transboundary biomass burning in Southeast Asia, $PM_{2.5}$ concentrations can spike to levels many times higher than these guidelines, posing serious health threats (Cheong et al., 2019). Many countries use the Air Quality Index (AQI) to communicate these risks to the public, with $PM_{2.5}$ concentrations in the "very unhealthy" or "hazardous" range prompting emergency public health advisories and school or workplace closures (U.S. EPA, 2023). These internationally recognized metrics are critical for monitoring air quality, issuing health warnings, and guiding coordinated policy responses to mitigate the impacts of haze.

Key relevant UN convention / multilateral treaty

Not applicable.

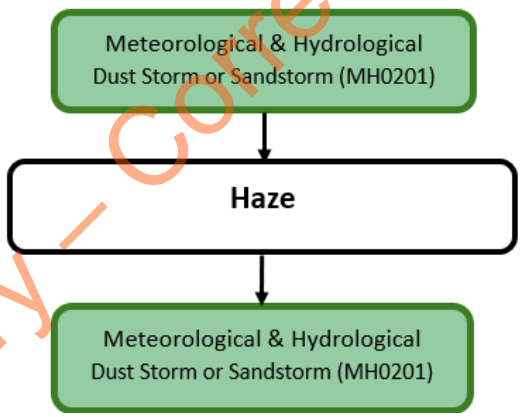
Examples of hazard drivers, impacts, and risk management

Hazard Drivers: In meteorology, haze is caused by suspended dry solid particles in the air, such as dust or salt. Haze is an atmospheric phenomenon in meteorological observation and the particles of which it is formed are termed lithometeors (AMS, 2012).

Impacts: It can obscure vision and directly influence horizontal visibility (AMS, 2012).

Exposure to haze, particularly from transboundary pollution events in Southeast Asia, has been shown to cause various adverse health effects, with risks escalating significantly with prolonged exposure. Short-term contact with haze can lead to respiratory irritation, reduced lung function, and exacerbation of existing cardiovascular and respiratory conditions. Long-term or repeated exposure, however, has been associated with more severe health outcomes, including increased hospital admissions, heightened mortality risk, and chronic respiratory diseases (Cheong et al., 2019). These findings underscore the critical need for effective public health interventions and regional cooperation to mitigate the health impacts of recurrent haze episodes.

Multi-hazard Context: The figure below summarises common interactions between haze and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section above and the table below offer an overview of monitoring haze. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• National, subnational, and local disaster management agencies responsible for monitoring haze-related risks, issuing warnings, and coordinating emergency response. • Meteorological service tracking atmospheric conditions, temperature inversions, and wind patterns that contribute to haze formation and dispersion. • Air quality monitoring agencies measuring particulate matter (PM2.5, PM10), visibility levels, and pollution sources using ground sensors and satellite observations. • Geophysical and atmospheric research institutions studying aerosol dynamics, pollution transport, and long-term climate effects of haze. • Health authorities assessing public health impacts of haze exposure, including respiratory illnesses, cardiovascular risks, and emergency medical preparedness. • Energy and industrial regulatory agencies monitoring emissions from factories, power plants, and vehicle exhaust that contribute to haze formation. • Forestry and land management agencies tracking wildfires, deforestation, and agricultural burning that release smoke and pollutants into the atmosphere. • Transportation and aviation authorities assessing visibility hazards for road, rail, and air travel and issuing safety advisories.

Preliminary – Corrections Pending

	• Space and remote sensing agencies using satellite technology to track haze movement, pollution hotspots, and air quality trends. • Researchers and academics, including climatologists and environmental scientists, studying haze formation, climate interactions, and mitigation strategies. • Environmental organisations and conservation groups advocating for clean air policies, emission reduction measures, and sustainable land-use practices.
How is the Hazard Observed/Monitored/Forecast?	Haze is monitored using ground-based air quality sensors, satellites, and weather radar to track fine particulate matter (PM2.5, PM10) and visibility levels. Meteorologists analyse wind patterns, humidity, and pollution sources such as wildfires and industrial emissions to predict haze formation and movement. Computer models simulate air pollution dispersion, helping forecasters issue warnings. These alerts help protect public health, aviation, and transportation by providing guidance on air quality and visibility conditions.

Risk Management: Risk management for haze involves coordinated strategies across monitoring, early warning, public health protection, and long-term emission reduction. Key measures include the use of air quality monitoring networks to track fine particulate matter ($PM_{2.5}$) and issue timely advisories when concentrations exceed health-based thresholds, such as those recommended by the World Health Organization (WHO, 2021). Governments often implement short-term responses, including school closures, distribution of masks, and public guidance to remain indoors during severe haze events (Cheong et al., 2019). A notable example of haze risk management is Singapore's transboundary haze action plan, which integrates real-time monitoring, a Pollutant Standards Index (PSI)-based alert system, and cross-border collaboration with ASEAN countries to reduce regional biomass burning (National Environment Agency, 2023). Alerts are conveyed to the public through multiple channels, including mobile apps, SMS notifications, government websites, and daily media broadcasts, enabling individuals and institutions to take timely protective actions. Long-term mitigation involves policies promoting sustainable land management, stricter enforcement against illegal burning, and cleaner energy transitions to reduce the root causes of haze.

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Coordinating agency or organisation

World Meteorological Organization (WMO).

Preliminary – Corrections Pending

MH0204 / METEOROLOGICAL AND HYDROLOGICAL / Particle-related

Sand haze (Dust haze)

Definition

A dust haze (or sand haze) is a suspension in the air of dust or small sand particles raised from the ground prior to the time of observation by a dust storm or sandstorm. The dust storm or sandstorm may have occurred either at or near the observation site or far from it (WMO, 2025).

Reference

WMO, 2025. *Dust haze.* International Cloud Atlas. https://cloudatlas.wmo.int/en/dust-haze.html Accessed 16 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Not available.

Additional scientific description

Although the World Meteorological Organization (WMO) defines a dust episode with the aforementioned characteristics as "dust haze," the American Meteorological Society (AMS) describes a similar phenomenon as "sand haze."

According to the American Meteorological Society, sand haze is the reduced visibility in the atmospheric boundary layer caused by suspended particles of soil mixed into the air during strong winds. Sand haze is particularly prevalent in desert regions where there is little moisture and few plants to hold the sand grains to the surface. After sandstorm the larger sand grains will fall out of the air quickly, leaving a sand haze of medium size particles (1-100 µm diameters, including silt and fine sand) and small particles (coarse (2.5-10 µm), fine (<2.5 µm)) (AMS, 2024).

The International Knowledge Centre for Engineering Sciences and Technology (IKCEST) has also called dust haze an “atmospheric brown cloud”. According to Specifications for Surface Meteorological Observation of China Meteorological Administration, dust haze is defined as: “a huge amount of dry dust particles that are extremely subtle are flowing evenly-scattered in air, making air unclear with the visibility no more that 10km and bringing yellow and red colour to lighting facilities. They seem a little blue if they are under darkness (IKCEST, 2018).

Metrics and numeric limits

According to the China Meteorological Bureau 2003 Dust haze (or sand haze) is identified primarily by visibility thresholds and particulate matter concentrations. It is defined as a reduction in visibility to less than 10 kilometres due to high concentrations of particulate matter in the air (Weiping et al., 2003). According to the China Meteorological Press 2014, dust haze is a daily visibility <10 km with relative humidity <90%. This definition can be divided into light (8-10 km), medium (5-8 km) and heavy dust haze (<5 km). These thresholds provide a clear framework for observing and categorising haze events based on their intensity (Liu et al., 2014).

Particulate matter (PM) concentrations are a significant factor in dust haze formation. In regions such as Inner Mongolia and northern China, "dusty air" days have been associated with PM_{10} concentrations ranging between 50 and 200 µg/m³. These high concentrations contribute to persistent haze, especially under calm weather conditions when particulate matter remains suspended in the lower atmosphere (Hoffman, 2008).

Relative humidity plays a critical role in the formation and persistence of dust haze. It is typically observed when relative humidity levels are below 90%, as low humidity prevents the aggregation and settling of fine particles. This allows smaller particles, such as silt and clay, to remain suspended in the atmosphere for extended periods, maintaining reduced visibility conditions (Liu et al., 2014).

The size distribution of particles in dust haze events varies depending on the source and environmental conditions. After a sandstorm, larger sand particles settle quickly, while finer particles between 1-100 µm (including silt and clay) stay airborne, forming the visible

haze. Smaller particles, often less than 1 µm in diameter, including clay and mineral dust, contribute significantly to the longevity of dust haze in the atmosphere (AMS, 2024).

Key relevant UN convention / multilateral treaty

- Considering that dust haze (or sand haze) originates from dust storms and sand storms, most multilateral conventions and treaties established to address these hazards on a global scale can also be effectively applied to mitigate the risks associated with dust haze.
- United Nations Coalition on Combating Sand and Dust Storms (FAO, no date).
- International Partnership for Sand and Dust Storms Early Warnings (WMO, no date).
- United Nations Environment Assembly (UNEA) Resolutions on Sand and Dust Storms (UNEA, no date).
- United Nations Decade on Combating Sand and Dust Storms (2025-2034) (United Nations, no date).
- United Nations Convention to Combat Desertification (UNCCD) (UNCCD, no date).
- United Nations Framework Convention on Climate Change (UNFCCC) (UNFCCC, no date).

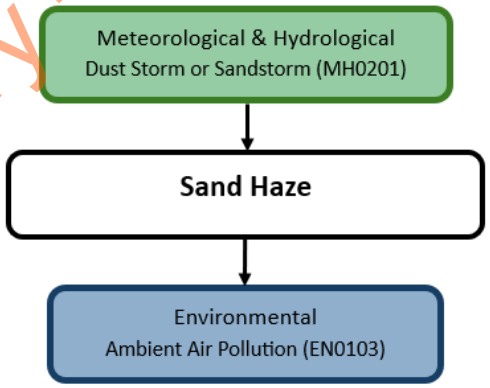
Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Dust/sand haze is caused by both natural and human factors. Natural drivers include strong winds, arid climates, and sparse vegetation, which allow dust and sand particles to become airborne. Human activities like overgrazing, deforestation, unsustainable farming, and land degradation worsen the problem. Climate change intensifies these events by increasing droughts, reducing soil moisture, and boosting wind speeds. Urbanisation and industrialisation also add particulate matter through emissions and construction (Middleton et al., 2024).

Impacts: Dust haze contains fine particulate matter, including sulphates, nitrates, black carbon, and mineral dust. Particles smaller than 10 microns (PM10) can lodge in the lungs, while those under 2.5 microns (PM2.5) can enter the bloodstream, causing cardiovascular and respiratory diseases, lung cancer, and other health issues. Dust also carries pathogens like bacteria and fungi that can spread infectious diseases (WHO, 2018; Agache et al., 2024). Even low levels of particulate pollution have harmful health effects, with no safe threshold (WHO, 2018).

Economically, dust haze reduces crop yields, disrupts transportation due to low visibility, and raises healthcare costs. Psychologically, prolonged exposure can lead to stress and anxiety, especially in affected communities (WHO, 2024).

Multi-hazard Context: The figure below summarises common interactions between sand haze and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Preliminary – Corrections Pending

Monitoring: The section above and the table below offer an overview of monitoring sand haze. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• National, subnational, and local disaster management agencies responsible for monitoring sand haze risks, issuing warnings, and coordinating emergency response efforts. • Meteorological service tracking wind patterns, atmospheric pressure, and weather conditions that contribute to sand haze formation and movement. • Air quality monitoring agencies measuring airborne particulate matter (PM10, PM2.5) and visibility conditions using ground-based sensors and satellite observations. • Geophysical and atmospheric research institutions studying dust transport, desertification, and long-term climate impacts of sand haze.

	• Health authorities assessing public health risks, including respiratory illnesses, eye irritation, and emergency response planning for air pollution events. • Agriculture and land management agencies monitoring soil erosion, desertification, and the impact of sand haze on crops, livestock, and ecosystems. • Energy and utility companies evaluating risks to power generation facilities, solar energy farms, and wind turbines from sand accumulation. • Transportation and aviation authorities monitoring visibility conditions and issuing advisories for road, rail, and air travel disruptions caused by sand haze. • Space and remote sensing agencies using satellites and LiDAR technology to track the movement of sand haze and its intensity over different regions. • Researchers and academics, including climatologists and environmental scientists, studying sand haze frequency, climate interactions, and mitigation strategies. • Environmental organisations and conservation groups promoting soil conservation, reforestation, and land management practices to reduce dust haze formation.
How is the Hazard Observed/Monitored/Forecast?	Sand haze (dust haze) is monitored using satellites, ground-based air quality sensors, and weather radar to track airborne dust levels and visibility conditions. Meteorologists analyse wind patterns, humidity, and desert surface conditions to predict when and where haze will form and how far it will spread. Computer models simulate dust movement, helping forecasters issue warnings. These alerts protect public health, transportation, and industries by providing guidance on air quality and visibility hazards.

Risk Management: Effective strategies include early warning systems, sustainable land management, and international collaboration. Early warnings from organisations like the WMO help communities prepare for dust storms. Global partnerships, such as the UN Coalition on Combating Sand and Dust Storms, foster coordinated mitigation efforts (Middleton et al., 2024).

The Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS), established by the World Meteorological Organization (WMO), enhances global coordination in monitoring, forecasting, and assessing sand and dust storms (WMO, no date a). Operating through regional centres in Barcelona, Beijing, and Barbados, SDS-WAS supports early warning systems and risk mitigation efforts in sectors such as health, aviation, and agriculture (WMO, no date b). It also contributes to the work of the United Nations Coalition on Combating Sand and Dust Storms by improving access to timely, science-based information for decision-making.

Sustainable land management practices, including reforestation and soil conservation, address root causes. Climate change adaptation policies, like reducing emissions and improving water management, help mitigate long-term impacts. Public health measures, such as stricter air quality standards, protective equipment, and awareness campaigns, reduce health risks (Middleton et al., 2024; Salehi et al., 2019).

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World Meteorological Organization (WMO), no date c. Dust haze. International Cloud Atlas. Available at: https://cloudatlas.wmo.int/en/dust-haze.html Accessed 31 January 2025.

Coordinating agency or organisation

World Meteorological Organization (WMO).

Preliminary – Corrections Pending

MH0205 / METEOROLOGICAL AND HYDROLOGICAL / Particle-related

Smoke

Definition

Smoke is a suspension in the air of small particles produced by combustion (WMO, 2017).

Reference

WMO, 2017. Smoke. International Cloud Atlas, World Meteorological Organization (WMO). https://cloudatlas.wmo.int/smoke.html Accessed 16 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Not relevant

Additional scientific description

This lithometeor may be present either near the Earth's surface or in the free atmosphere. Viewed through smoke, the Sun appears very red at sunrise and sunset and shows an orange tinge when high in the sky. Smoke from relatively near cities may be brown, dark grey or black. Smoke in extensive layers originating from fairly near forest fires scatters the sunlight and gives the sky a greenish-yellow hue. Evenly distributed smoke from very distant sources generally has a light greyish or bluish hue. When smoke is present in large quantities, it may be distinguished by its smell (WMO, 2017).

When the lithometeor 'smoke' is present in the free atmosphere, it is typically distinguished from clouds of smoke (clouds from fires or resulting from industry) by its diffuse appearance and by the absence of any discernible outlines (WMO, 2017).

Air quality is also compromised by natural contaminants such as aeroallergens (pollen, moulds), smoke from wildfires, airborne sand and dust, as well as by personal behaviour such as tobacco smoke exposure or indoor burning of solid fuels. When inhaled, these contaminants penetrate deeply into the respiratory system and may initiate a range of damaging biological reactions in the human body (WMO, 2014). As a result, air pollution is now one of the world's greatest environmental health risks.

Metrics and numeric limits

Not available.

Key relevant UN convention / multilateral treaty

Not available.

Examples of hazard drivers, impacts, and risk management

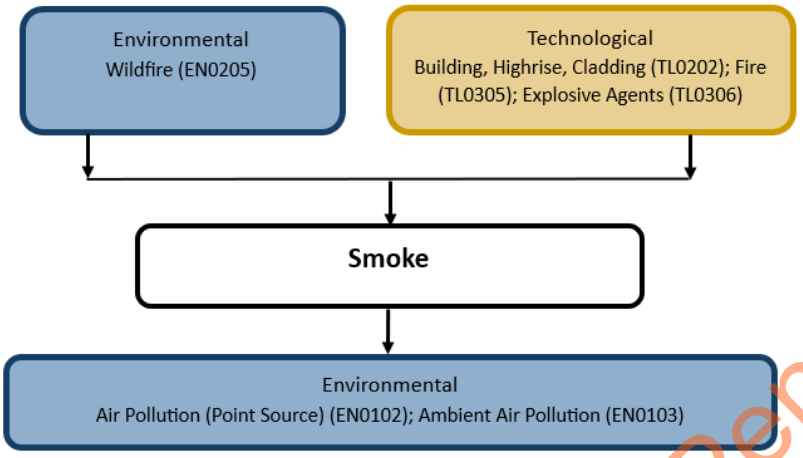
Hazard Drivers: Smoke results from fires.

Impacts: Smoke contains particulate matter, which is a common proxy for air pollution. The major components of atmospheric particulates are sulphates, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water. It consists of a complex mixture of solid and liquid particles of organic and inorganic substances suspended in the air. While particles with a diameter of 10 microns or less (≤ PM10) can penetrate and lodge deep inside the lungs, the even more health-damaging particles are those with a diameter of 2.5 microns or less (≤ PM2.5). The latter can penetrate the lung barrier and enter the blood system. Chronic exposure to particles contributes to the risk of developing cardiovascular and respiratory diseases, as well as lung cancer (see HIPs on carcinogens CH0200) (WHO, 2018).

Small particulate pollution has health impacts even at very low concentrations, and no threshold has been identified below which no damage to health is observed. Therefore, the WHO 2005 guideline limits aim to achieve the lowest concentrations of particulate matter possible (WHO, 2018).

Multi-hazard Context: The figure below summarises common interactions between smoke and other hazards. This information should

be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section above and the table below offer an overview of monitoring smoke. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• National, subnational, and local disaster management agencies responsible for monitoring wildfire and industrial smoke risks, issuing warnings, and coordinating emergency response. • Meteorological service tracking wind patterns, temperature inversions, and weather conditions influencing smoke dispersion. • Air quality monitoring agencies measuring levels of pollutants such as PM2.5, PM10, carbon monoxide (CO), and volatile organic compounds (VOCs) using ground-based sensors and satellite observations. • Geophysical and atmospheric research institutions studying smoke transport, climate interactions, and long-term air pollution effects. • Health authorities assessing public health risks related to respiratory illnesses, cardiovascular effects, and emergency response strategies for smoke exposure. • Forestry and wildfire management agencies monitoring forest fires, agricultural burning, and industrial activities that generate smoke emissions. • Energy and industrial regulatory agencies overseeing emissions from power plants, manufacturing, and industrial processes that contribute to smoke pollution. • Transportation and aviation authorities monitoring visibility conditions and issuing advisories for road, rail, and air travel disruptions due to smoke. • Space and remote sensing agencies using satellites, LiDAR, and thermal imaging to track smoke plumes, wildfire hotspots, and air quality changes. • Researchers and academics, including atmospheric scientists and environmental health experts, studying smoke dispersion, health impacts, and mitigation strategies. • Environmental organisations and conservation groups advocating for air pollution control policies, wildfire prevention, and sustainable land management practices.
How is the Hazard Observed/Monitored/Forecast?	Smoke is monitored using satellites, ground-based air quality sensors, and weather radar to track pollution levels, wildfire activity, and smoke dispersion. Meteorologists analyse wind patterns, humidity, and fire conditions to predict how smoke will spread. Computer models simulate smoke movement, helping forecasters issue air quality warnings. These alerts help protect public health, transportation, and communities by providing guidance on exposure risks and safety measures.

Risk Management: The World Meteorological Organization (WMO) has responded to urgent requests for assistance from Members in several impacted regions by initiating a Vegetation Fire and Smoke Pollution Warning and Advisory System (VFSP-WAS) (WMO, 2019). This provides guidance for addressing both fire and smoke hazards and proposes to support the potential foundation of regional centres to address air quality and the impact of smoke.

The Southeast Pacific, one of the regions most affected by vegetation fires and smoke pollution, has established the first Regional Vegetation Fire and Smoke Pollution Warning and Advisory Centre, operated by the Meteorological Service of Singapore. The Southeast Pacific Centre serves as a prototype for other centres to be established around the world.

Preliminary – Corrections Pending

Smoke is one of the many causes of air pollution. Air pollution is a major environmental risk to health. By reducing air pollution levels, countries can reduce the burden of disease from stroke, heart disease, lung cancer, and both chronic and acute respiratory diseases, including asthma. The lower the levels of air pollution, the better the cardiovascular and respiratory health of the population, both long- and short-term. The World Health Organization has published an assessment of the health effects of air pollution and thresholds for health-harmful pollution levels (WHO, 2018).

References

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Coordinating agency or organisation

World Meteorological Organization (WMO).

Preliminary – Corrections Pending

MH0301 / METEOROLOGICAL AND HYDROLOGICAL / Wind- & Pressure-related

Wind

Definition

Wind is air motion relative to the Earth's surface. Unless otherwise specified, only the horizontal component is considered (WMO, 1992).

Reference

WMO, 1992. International Meteorological Vocabulary. WMO-No. 182. World Meteorological Organization (WMO). https://library.wmo.int/records/item/35809-international-meteorological-vocabulary?offset=2 Accessed 16 May 2025.

Annotations

Synonyms

Not identified.

Additional scientific description

Wind velocity is an important consideration in relation to, for example, airborne pollution and the landing of aircraft (WMO, 2018). Surface wind is considered mainly as a two-dimensional vector quantity specified by two numbers representing direction and speed (WMO, 2018).
The extent to which wind is characterised by rapid fluctuations is referred to as gustiness, and single fluctuations are called gusts (WMO, 2018).

Metrics and numeric limits

An internationally recognised scale for measuring wind is the Beaufort Scale, which is an empirical measure that relates wind speed to observed conditions at sea or on land. Its full name is the Beaufort wind force scale (Royal Meteorological Society, 2018).

The Beaufort wind force scale has 13 levels, including: calm, light air, light breeze, gentle breeze, moderate breeze, fresh breeze, strong breeze, near gale, gale, strong gale, storm, violent storm, and hurricane. Of note, the quoted wind speed is that measured at 10 m above ground, not at the surface (which, at 2 m, may be only 50-70% of these values (Royal Meteorological Society, 2018).

Key relevant UN convention / multilateral treaty

Not identified.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Earth's orbit around the sun and its rotation on a tilted axis causes some parts of Earth to receive more solar radiation than others. This uneven heating produces global circulation patterns. For example, the abundance of energy reaching the equator produces hot, humid air that rises high into the atmosphere. A low-pressure area forms at the surface, and a region of clouds forms at altitude. The air eventually stops rising and spreads north and south towards the Earth's poles. About 2000 miles (3200 km) from the equator, the air falls back to Earth's surface, blowing towards the pole and back to the equator. Six of these large convection currents cover the Earth from pole to pole. (NOAA, 2024).

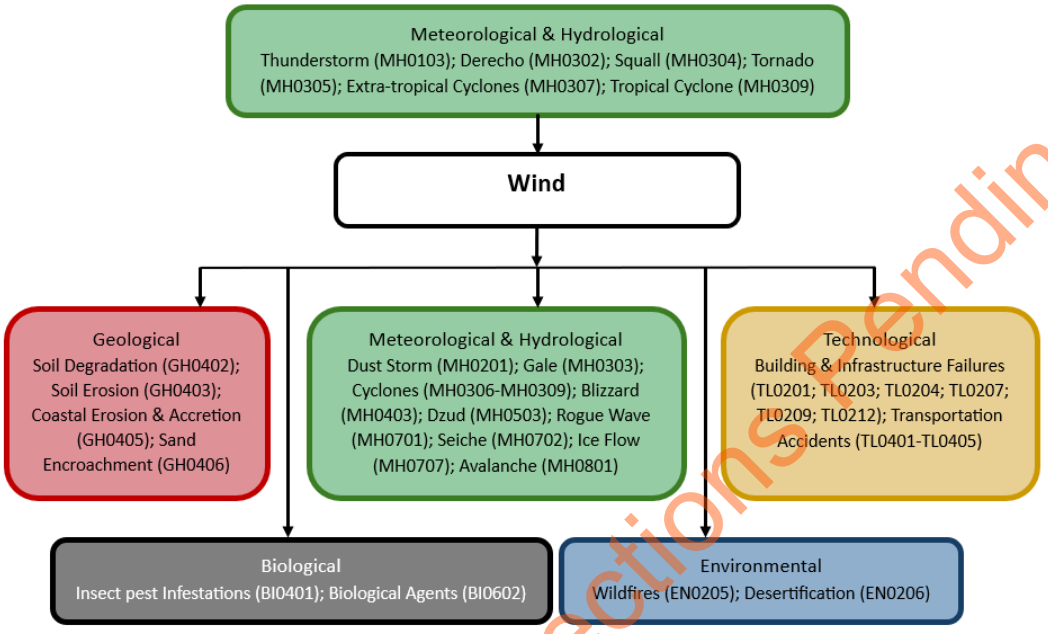
Impacts: Wind is a main or contributing component to a number of hazards such as derecho, tropical cyclone, blizzard, sub-tropical cyclone, subtropical storm, tornado, and tropical storm. Wind is also associated with the dispersal of dust storms, volcanic ash and coastal floods.

Human health can be severely affected by windstorms (Goldman et al., 2014). Effects include direct effects, which occur during the impact phase of a storm, causing death and injury due to the force of the wind. Becoming airborne, being struck by flying debris or falling trees and road traffic accidents are the main dangers. Indirect effects, occurring during the pre- and post-impact phases of the storm, include falls, lacerations and puncture wounds, and occur when preparing for, or cleaning up after a storm. Power outages are a key issue and can lead to electrocution, fires and burns, and carbon monoxide (CH0302) poisoning from gasoline-

Preliminary – Corrections Pending

powered electrical generators. Worsening of chronic illnesses due to lack of access to medical care or medication can also occur. Other health impacts include infections and insect bites.

Multi-hazard Context: The figure below summarises common interactions between wind and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section above and the table below offer an overview of monitoring wind. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• National, subnational, and local disaster management agencies responsible for monitoring high wind risks, issuing warnings, and coordinating emergency response efforts. • Meteorological organisations tracking wind speeds, pressure systems, and severe weather events. • Maritime and aviation safety authorities monitoring wind conditions and issuing advisories for ships, ports, aircraft, and offshore operations. • Transportation and infrastructure agencies assessing risks to roads, bridges, and railways from strong winds. • Energy and utility companies monitoring risks to power lines, wind turbines, and other infrastructure from extreme winds and windstorms. • Health authorities evaluating public safety risks, including injuries from debris, structural collapses, and emergency medical response needs. • Researchers and academics, including meteorologists, climatologists, and engineers, studying wind patterns, extreme wind events, and wind-resistant building designs.
How is the Hazard Observed/Monitored/Forecast?	Winds are monitored using weather stations and satellites to measure wind speed, direction, and atmospheric pressure changes. Meteorologists analyse pressure systems, jet streams, and storm patterns to predict wind velocity and direction. Advanced weather models forecast extreme wind conditions, helping forecasters issue early warnings. These warnings assist aviation, maritime industries, emergency responders, and communities in preparing for strong winds, storms, and potential damage.

Risk Management: Building codes to ensure buildings are resilient to strong winds are implemented in some countries.

References

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Coordinating agency or organisation

World Meteorological Organization (WMO).

Preliminary – Corrections Pending

MH0302 / METEOROLOGICAL AND HYDROLOGICAL / Wind- & Pressure-related

Derecho

Definition

Derechos are fast-moving bands of thunderstorms with destructive winds. The winds can be as strong as those found in hurricanes or even tornadoes. Unlike hurricanes and tornadoes, these winds follow straight lines (NOAA, 2019).

Reference

NOAA, 2019. What is a Derecho? National Oceanic and Atmospheric Administration (NOAA). https://scijinks.gov/derechos Accessed 16 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Not applicable.

Additional scientific description

A derecho (pronounced similar to 'deh-REY-cho') is a widespread, long-lived windstorm that is associated with a band of rapidly moving showers or thunderstorms. Although a derecho can produce destruction similar to the strength of tornadoes, the damage is typically directed in one direction along a relatively straight swath. As a result, the term 'straight-line wind damage' is sometimes used to describe derecho damage. By definition, if the wind damage swath extends more than 240 miles (about 400 km) and includes wind gusts of at least 58 mph (93 km/h) or greater along most of its length, then the event may be classified as a derecho (NOAA, 2019).

A derecho is a widespread convectively induced straight-line windstorm. Specifically, the term is defined as any family of particularly damaging downburst clusters produced by a mesoscale convective system (AMS, 2012a). Such systems have sustained bow echoes with book-end vortices and/or rear-inflow jets and can generate considerable damage from straight-line winds. Damage must be incurred either continuously or intermittently over a swath of at least 650 km (~400 miles) and a width of approximately 100 km (~60 miles) or more. The term derecho derives from a Spanish word that can be interpreted as 'straight ahead' or 'direct' and was chosen to distinguish between wind damage caused by tornadoes (AMS, 2012b), which have rotating flow, from straight-line winds.

The National Oceanic and Atmospheric Administration Storm Prediction Center reports that the types of derecho include: serial derechos, progressive derechos, hybrid derechos and low-point derechos (NOAA, 2018).

Metrics and numeric limits

The winds associated with derechos are not constant and may vary considerably along the derecho path, sometimes being below severe limits (57 mph [92 km/h] or less) and sometimes being very strong (from 75 mph [121 kph] to over 100 mph [161 kph]). This is because the swaths of stronger winds within the general path of a derecho are produced by what are called downbursts, and downbursts often occur in irregularly arranged clusters, along with embedded microbursts and burst swaths. Derechos might be said to be made up of families of downburst clusters that extend, by definition, continuously or nearly continuously for at least 250 miles (about 400 km) (NOAA, 2018).

Key relevant UN convention / multilateral treaty

Not identified.

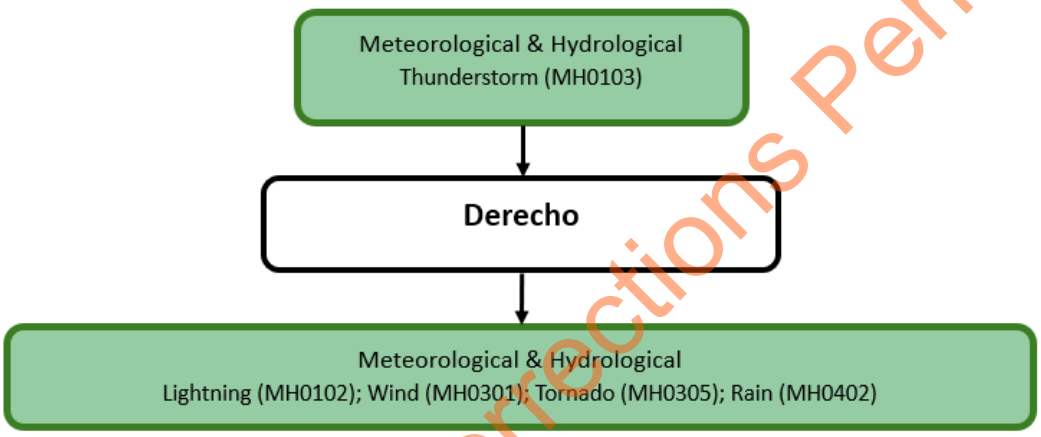
Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Derechos are formed as follows. When the wet air in a thunderstorm meets the drier air surrounding it, the water in the air evaporates. When water evaporates, it cools the air around it. Since the cool air is denser, it rapidly sinks

to the ground and creates strong winds. The downburst can suck more dry air into the storm, making even stronger downbursts or clusters of downbursts. Derechos occur when the right conditions for downbursts occur over a wide area (NOAA, 2019). See also NOAA (2018) for more detailed information about derechos.

Impacts: Because derechos are most common in the warm season, those involved in outdoor activities are especially at risk. Campers or hikers in forested areas are vulnerable to being injured or killed by falling trees, and those at sea risk injury or drowning from storm winds and high waves that can overturn boats. Another reason people outdoors are especially vulnerable to derechos is the rapid movement of the parent convective system. Typically, derecho-producing storm systems move at speeds of 50 mph or more, and a few have been recorded at 70 mph. For someone caught outside, such rapid movement means that darkening skies and other visual cues that serve to identify the impending danger (e.g., gust front shelf clouds) appear at very short notice (NOAA, 2018).

Multi-hazard Context: The figure below summarises common interactions between derechos and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section above and the table below offer an overview of monitoring derechos. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• National, subnational, and local disaster management agencies responsible for monitoring derechos, issuing warnings, and coordinating emergency response efforts. • Meteorological services tracking atmospheric conditions that contribute to derecho formation using satellites and Doppler radar to detect storm development and wind speeds. • Hydrological services monitoring rainfall intensity, flash flood risks, and stormwater runoff associated with derechos. • Transportation and infrastructure agencies assessing risks to roads, bridges, railways, and airports from extreme winds and debris. • Energy and utility companies monitoring risks to power grids, wind turbines, and electrical infrastructure due to high winds and falling debris. • Health authorities evaluating public safety risks, including injuries from flying debris, structural collapses, and emergency medical response needs. • Researchers and academics, including meteorologists and climatologists, studying derecho formation, dynamics, wind shear effects, and forecasting improvements.
How is the Hazard Observed/Monitored/Forecast?	Derechos are monitored using Doppler radar, weather satellites, and ground-based sensors that track cloud structures, wind patterns, and lightning activity. Meteorologists analyse key atmospheric conditions, including temperature, humidity, and wind shear, to assess the potential development and intensity of these widespread, fast-moving storms. By integrating advanced numerical weather models with real-time observational data, forecasters improve the accuracy of derecho predictions and track their movement. This enables timely warnings to mitigate risks to aviation, infrastructure, and communities from associated hazards such as damaging straight-line winds, heavy rainfall, lightning, and hail.

Risk Management: No Information Available

Preliminary – Corrections Pending

References

American Meteorological Society (AMS), 2012a. Glossary of Meteorology: Mesoscale Convective System. [online] Available at: https://glossary.ametsoc.org/wiki/Mesoscale_convective_system Accessed 16 May 2025.

American Meteorological Society (AMS), 2012b. Glossary of Meteorology: Tornado. [online] Available at: https://glossary.ametsoc.org/wiki/Tornado Accessed 16 May 2025.

American Meteorological Society (AMS), 2019. Glossary of Meteorology: Derecho. [online] Available at: http://glossary.ametsoc.org/wiki/Derecho Accessed 16 May 2025.

National Oceanic and Atmospheric Administration (NOAA), 2018. About Derechos. Storm Prediction Center, [online] Available at: https://www.spc.noaa.gov/misc/AbtDerechos/derechofacts.htm#strength Accessed 16 May 2025.

\National Oceanic and Atmospheric Administration (NOAA), 2019. Derecho. National Weather Service, [online] Available at: https://www.weather.gov/lmk/derecho Accessed 16 May 2025.

Coordinating agency or organisation

World Meteorological Organization (WMO).

Preliminary – Corrections Pending

MH0303 / METEOROLOGICAL AND HYDROLOGICAL / Wind- & Pressure-related

Gale (Strong Gale)

Definition

A gale is wind with a speed of between 34 and 40 knots (62-74 km/h, 32-38 mph). Also known as Beaufort scale wind force 8 (WMO, 1992).

Reference

WMO, 1992. International Meteorological Vocabulary. WMO-No. 182. World Meteorological Organization (WMO). https://library.wmo.int/records/item/35809-international-meteorological-vocabulary?offset=2 Accessed 16 May 2025.

Annotations

Synonyms

Not found.

Additional scientific description

The numerical limits of a gale are defined by the Beaufort Scale, which is an empirical measure that relates wind speed to observed conditions at sea or on land (Royal Meteorological Society, 2018). Its full name is the Beaufort wind force scale.

Metrics and numeric limits

A gale is wind with a speed of between 34 and 40 knots (62-74 km/h, 32-38 mph). Also known as Beaufort scale wind force 8 (WMO, 1992).

Key relevant UN convention / multilateral treaty

Not applicable.

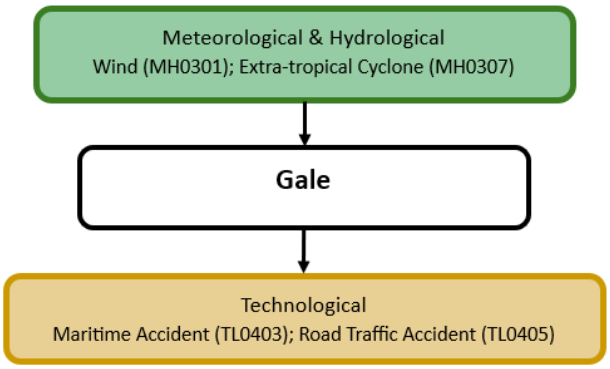
Examples of hazard drivers, impacts, and risk management

Hazard Drivers: No Information Available

Impacts: Human health can be severely affected by windstorms. Direct effects occur during the impact phase of a storm, causing death and injury due to the force of the wind. Becoming airborne, being struck by flying debris or falling trees and road traffic accidents are the main dangers. Indirect effects, occurring during the pre- and post-impact phases of the storm, include falls, lacerations and puncture wounds, and occur when preparing for, or cleaning up after a storm. Power outages are a key issue and can lead to electrocution, fires, burns and carbon monoxide poisoning (CH0302) from gasoline-powered electrical generators. In addition, worsening of chronic illnesses due to lack of access to medical care or medication can occur. Other health impacts include infections and insect bites (Goldman et al., 2014).

Multi-hazard Context: The figure below summarises common interactions between gales and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

Preliminary – Corrections Pending



Monitoring: The section above and the table below offer an overview of monitoring gales. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• National, subnational, and local disaster management agencies responsible for monitoring gale-force wind risks, issuing warnings, and coordinating emergency response efforts. • Meteorological organisations tracking wind speeds, atmospheric pressure changes, and storm systems that develop gales. • Space and remote sensing agencies using satellites and radar to track wind speeds, cloud movement, and temperature variations. • Maritime and naval safety authorities monitoring ocean conditions and issuing advisories for shipping, ports, and offshore industries due to gale-force winds. • Transportation and infrastructure agencies assessing risks to roads, bridges, railways, and airports from strong winds and flying debris. • Energy and utility companies monitoring risks to power grids, wind turbines, and transmission lines from high winds and infrastructure strain. • Health authorities evaluating public safety risks, including injuries from debris, structural collapses, and emergency medical response needs. • Researchers and academics, including meteorologists and climatologists, studying wind patterns, storm development, and climate change impacts on gale events.
How is the Hazard Observed/Monitored/Forecast?	Gales are monitored using ground-based wind sensors, weather observations, radar, and satellites to track wind speeds and pressure changes. Meteorologists analyse atmospheric pressure gradients and storm movement to predict gale formation. Advanced weather models forecast wind patterns, helping forecasters issue early warnings. These alerts assist mariners, aviation authorities, and communities in preparing for strong winds, rough seas, and potential infrastructure damage.

Risk Management: Many countries have National Alerting Parameters for Gale, including the Philippines (PAGASA, no date), China (China Meteorological Administration, 2012), the Republic of Korea (Korea Meteorological Administration, 2019) and the United States (NOAA, 2019).

References

China Meteorological Administration, 2012. Gale. www.cma.gov.cn/en/WeatherWarnings/WarningSignals/201203/t20120320_166873.html Accessed 16 May 2025.

Goldman, A., B. Eggen, B. Golding and V. Murray, 2014. The health impacts of windstorms: a systematic literature review. Public Health, 128:3-28.

Korea Meteorological Administration, 2019. Criteria for advisory/warning information. https://www.weather.go.kr/w/index.do Accessed 16 May 2025. https://web.kma.go.kr/eng/weather/forecast/standard_warning_info.jspNOAA, 2019. Coastal Warning Display Signals. National Weather Service, National Oceanic and Atmospheric Administration (NOAA). https://www.weather.gov/marine/cwd Accessed 16 May 2025.

PAGASA, no date. Gale Warning. https://bagong.pagasa.dost.gov.ph/marine/gale-warning Accessed 16 May 2025.

Royal Meteorological Society, 2018. The Beaufort Scale: How is wind speed measured? www.rmets.org/resource/beaufort-scale Accessed 16 May 2025.

WMO, 1992. International Meteorological Vocabulary. WMO-No. 182. World Meteorological Organization (WMO). https://library.https://library.wmo.int/records/item/35809-international-meteorological-vocabulary?offset=2 Accessed 16 May 2025.

Preliminary – Corrections Pending

57 **Coordinating agency or organisation**

58 World Meteorological Organization (WMO)

Preliminary – Corrections Pending

MH0304 / METEOROLOGICAL AND HYDROLOGICAL / Wind- & Pressure-related

Squall

Definition

A squall is an atmospheric phenomenon characterised by a very large variation of wind speed: it begins suddenly, has a duration of the order of minutes and decreases suddenly in speed. It is often accompanied by a shower or thunderstorm (WMO, 2018).

Reference

WMO, 2018. Manual on Codes, International Codes, Volume I.2. WMO-No. 306. World Meteorological Organization (WMO). https://library.wmo.int/records/item/35625-manual-on-codes-international-codes-volume-i-2 Accessed 16 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Not identified.

Additional scientific description

The National Oceanic and Atmospheric Administration (NOAA) National Weather Service describes a squall as follows (NOAA, 2019):

- A strong wind characterised by a sudden onset in which the wind speed increases to at least 16 knots and is sustained at 22 knots or more for at least one minute.
- In nautical use, a severe local storm considered as a whole, that is, winds, cloud mass and (if any) precipitation, thunder and lightning.

The American Meteorological Society describes a squall as follows (AMS, 2012):

- A strong wind characterised by a sudden onset, a duration of the order of minutes, and then a sudden decrease in speed. In U.S. observational practice, a squall is reported only if a wind speed of 16 knots or more is sustained for at least two minutes (thereby distinguishing it from a gust).
- In nautical use, a severe local storm considered as a whole, that is, winds and cloud mass and (if any) precipitation, thunder and lightning.

Metrics and numeric limits

Not available.

Key relevant UN convention / multilateral treaty

Not available.

Examples of hazard drivers, impacts, and risk management

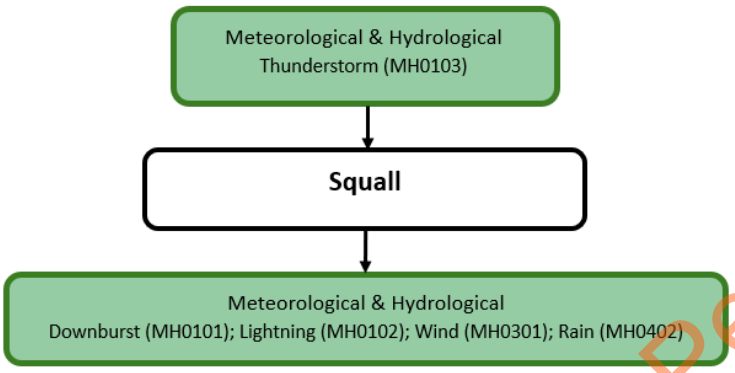
Hazard Drivers: Squalls occur during thunderstorms.

Impacts: Squalls are sudden changes in wind conditions. In general, a squall may not be very strong and may only last for a short time. However, owing to their unpredictability and sudden arrival, squalls pose a threat to marine operations that require a fairly calm sea state (Lu et al., 2018).

Human health can be severely affected by wind-related hazards such as squalls and windstorms. Direct effects occur during the impact phase of a storm, causing death and injury due to the force of the wind. Becoming airborne, being struck by flying debris or falling trees and road traffic accidents are the main dangers. Indirect effects, occurring during the pre- and post-impact phases of the storm, include falls, lacerations and puncture wounds, and occur when preparing for, or cleaning up after a storm. Power outages are a key issue and can lead to electrocution, fires and burns and carbon monoxide poisoning (CH0302) from gasoline

powered electrical generators. In addition, worsening of chronic illnesses due to lack of access to medical care or medication can occur. Other health impacts include infections and insect bites (Goldman et al., 2014).

Multi-hazard Context: The figure below summarises common interactions between squalls and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section above and the table below offer an overview of monitoring squalls. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• National, subnational, and local disaster management agencies responsible for monitoring squalls, issuing warnings, and coordinating emergency response efforts. • Meteorological services tracking atmospheric conditions that contribute to squall formation using satellites and Doppler radar to detect storm development and wind speeds. • Transportation and infrastructure agencies assessing risks to roads, bridges, railways, and airports from extreme winds and debris. • Energy and utility companies monitoring risks to power grids, wind turbines, and electrical infrastructure due to high winds and falling debris. • Health authorities evaluating public safety risks, including injuries from flying debris, structural collapses, and emergency medical response needs. • Researchers and academics, including meteorologists and climatologists, studying squall formation, dynamics, wind shear effects, and forecasting improvements.
How is the Hazard Observed/Monitored/Forecast?	Squalls are monitored using Doppler radar, weather satellites, and other remote sensing technologies that track cloud formations, wind patterns, and lightning activity. Meteorologists assess atmospheric conditions, including temperature, humidity, and wind shear, to predict the development and intensity of squalls. By integrating advanced numerical weather models with real-time observational data, forecasters can improve the accuracy of squall predictions and track their movement. This enables timely warnings to mitigate risks to aviation, infrastructure, and communities from associated hazards such as heavy rainfall, strong winds, lightning, and hail.

Risk Management: No Information Available

References

American Meteorological Society (AMS), 2012. Glossary of Meteorology: Squall. [online] Available at: http://glossary.ametsoc.org/wiki/Squall Accessed 16 May 2025.

Goldman, A., Eggen, B., Golding, B. and Murray, V., 2014. The health impacts of windstorms: a systematic literature review. Public Health, 128, pp.3-28.

Lu, Y., Ozaki, M. and Wada, R., 2018. Squalls in sea off coast of Japan and their effects on marine operations based on weather observatory data at remote islands. Journal of Marine Science and Technology, 23, pp.104-121.

National Oceanic and Atmospheric Administration (NOAA), 2019. National Weather Service Glossary: Squall. [online] Available at: https://forecast.weather.gov/glossary.php?word=SQUALL Accessed 16 May 2025.

Coordinating agency or organisation

World Meteorological Organization (WMO).

Preliminary – Corrections Pending

MH0305 / METEOROLOGICAL AND HYDROLOGICAL / Wind- & Pressure-related

Tornado

Definition

A tornado is a rotating column of air extending from the base of a cumuliform cloud and often visible as a condensation funnel in contact with the ground, and/or attendant circulating dust or debris cloud at the ground (WMO, 2017).

Reference

WMO, 2017. International Cloud Atlas: Tornado. World Meteorological Organization (WMO). https://cloudatlas.wmo.int/tornado.html Accessed 16 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Twister, Land spout, Cold air funnel, Waterspout, Funnel, Whirlwind, Dust Devil,

Additional scientific description

A large tornado in which the condensation funnel is at least as wide horizontally at the ground as it is in height from the ground to the cloud base may be referred to as a wedge tornado. During the dissipation stage of a tornado, the condensation funnel will shrink and narrow in width, becoming rope-like (a rope funnel), and may also become contorted. Some tornadoes may contain secondary vortices within the main circulation (suction vortices or subvortices) (WMO, 2017a).

Metrics and numeric limits

Tornadoes can be classified into the following distinct formation groups (WMO, 2017b): Type I (in association with supercells; WMO, no date), Type II (in association with quasi-linear convective systems), and Type III (localised convective and shear vortices – these comprise landspouts, waterspouts, and cold-air funnels).

Definitions for the Type III tornadoes are as follows (WMO, 2017b):

- *Landspout*: A tornado that does not arise from organised storm-scale rotation and is therefore not associated with a wall cloud (murus) or a mesocyclone.
- *Waterspout:* A tornado occurring over water. It is normally a relatively small, weak rotating column of air over open water below a Cumulonimbus or Cumulus congestus cloud.
- *Cold-air funnel:* A funnel cloud or (rarely) a small, relatively weak tornado that can develop from a small shower or thunderstorm when the air aloft is unusually cold.

The strength of a tornado is commonly estimated based on the extent and type of damage it causes. Various scales have been developed worldwide to classify tornado intensity, reflecting regional differences in damage patterns and assessment practices. The Enhanced Fujita (EF) Scale, introduced by the Storm Prediction Center (SPC) (2017a, n.d.), is the most widely used and has been adapted for use in countries such as Australia, South Africa, Canada, and Japan. In Europe, meteorological services typically employ the International Fujita (IF) Scale, as outlined by the European Severe Storms Laboratory (ESSL) in August 2023.

Key relevant UN convention / multilateral treaty

Not identified.

Examples of hazard drivers, impacts, and risk management

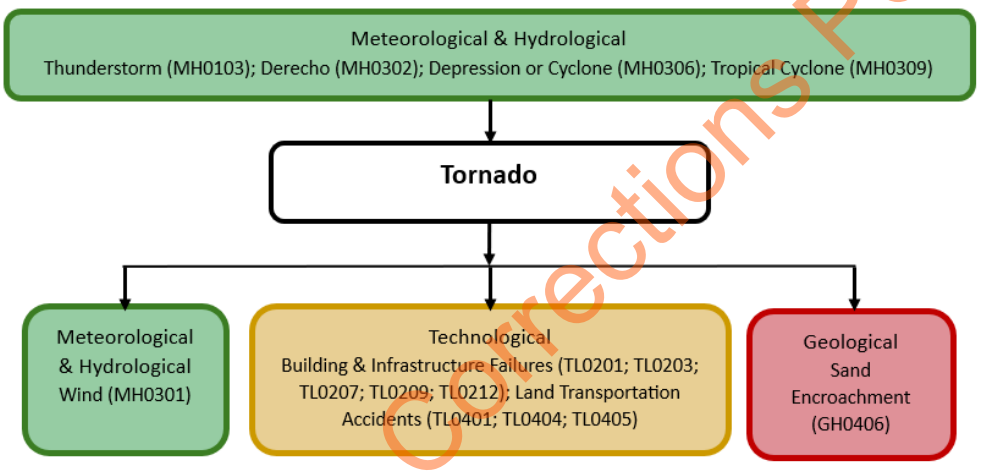
Hazard drivers: No information Available

Impacts: Impacts of tornadoes: Tornadoes have significant effects on human activities and communities, with the extent of tornado damage as a key component to the rating and wind speed estimations of tornado events (NOAA, 2024).

Impacts on Human Lives and Communities: Tornadoes pose severe risks to human life and safety due to their intense winds. Fatalities and injuries result from flying debris, structural collapses, and vehicles being overturned. According to the National Oceanic and Atmospheric Administration (NOAA), tornadoes caused an average of 71 fatalities annually in the United States (U.S.) between 1993 and 2022. Spring 2011 marked one of the deadliest tornado seasons recorded in the U.S., with over 580 people killed from April to June 2011, with the high death toll partly attributed to the rapid speed of the tornadoes that struck heavily populated areas with inadequate storm shelters (NOAA, 2024).

Damage to Infrastructure and economy: The economic costs of tornadoes are immense, with damages worth millions, and in some cases billions, per event. Tornadoes can cause significant damage to critical infrastructure and destroy homes, businesses, schools, and hospitals, creating significant challenges for rebuilding and recovery. For example, the EF-5 tornado that struck Joplin, Missouri, in 2011, caused losses of almost $3 billion, making it one of the costliest tornadoes in U.S. history (NIST, 2011). The 2011 Joplin tornado "damaged 553 business structures and nearly 7,500 residential structures; over 3,000 of those residences were heavily damaged or completely destroyed" (NIST, 2011).

Multi-hazard Context: The figure below summarises common interactions between tornadoes and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Preliminary – Corrections Pending

Monitoring: The section above and the table below offer an overview of monitoring tornadoes. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• National, subnational, and local disaster management agencies responsible for monitoring tornado risks, issuing warnings, and coordinating emergency response efforts. • Meteorological services tracking atmospheric instability, wind shear, and supercell thunderstorms that can produce tornadoes. • Hydrological services monitoring rainfall accumulation, flash flood risks, and storm-related flooding associated with tornado-producing thunderstorms. • Geophysical and atmospheric research institutions studying tornado dynamics, wind patterns of severe convective storms. • Aviation safety authorities monitoring severe weather conditions that impact flight operations. • Transportation and infrastructure agencies assessing risks to roads, railways, and airports from tornado-induced debris, wind damage, and associated hazards. • Energy and utility companies monitoring risks to power lines, electrical grids, and energy infrastructure from extreme winds and tornado-related destruction. • Health authorities evaluating public safety risks, including injuries, fatalities, and emergency medical response needs after tornado impacts. • Researchers and academics, including meteorologists and climatologists, studying tornado formation and forecasting improvements.
How is the Hazard Observed/Monitored/Forecast?	Tornadoes are monitored using Doppler radar, satellites, and ground-based weather stations to track storm rotation, wind speeds, and atmospheric pressure changes. Meteorologists analyse temperature differences, wind shear, and thunderstorm activity to predict tornado formation. Advanced computer models simulate storm behaviour, helping forecasters issue early warnings. These warnings assist emergency responders, communities, and infrastructure managers in preparing for potential destruction from high winds and flying debris.

Risk Management: Since the advent of Doppler Radar, lead times for tornado warnings have increased from when a tornado first touches the ground to upwards of 14 to 20 minutes or more beforehand (WMO, 2017b; National Geographic, 2019).

References

European Severe Storms Laboratory (ESSL), 2023. The International Fujita (IF) Scale for Tornado and Wind Damage Assessments. [online] 1 August. Available at: https://www.essl.org/cms/wp-content/uploads/IF-scale_v1.0d.pdf Accessed 16 May 2025.

National Geographic, 2019. What We Know – and What We Don't – About the Science of Tornadoes. [online] Available at: https://www.nationalgeographic.com/science/article/140430-tornadoes-meteorology-atmospheric-science-disasters Accessed 16 May 2025.

National Weather Service, no date. The Enhanced Fujita Scale (EF Scale). [online] Available at: https://www.weather.gov/oun/efscale Accessed 16 May 2025.

National Institute of Standards and Technology (NIST), 2011. Joplin Missouri Tornado 2011. [online] Available at: https://www.nist.gov/disaster-failure-studies/joplin-tornado Accessed 16 May 2025.

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World Meteorological Organization (WMO), 2017a. International Cloud Atlas: Manual on the Observation of Clouds and Other Meteors. WMO-No. 407. [online] Available at: https://library.wmo.int/records/item/66297-manual-on-the-observation-of-clouds-and-other-meteors-international-cloud-atlas Accessed 16 May 2025.

World Meteorological Organization (WMO), 2017b. Guidelines for Nowcasting Techniques. WMO-No. 1198. [online] Available at: https://library.wmo.int/viewer/55666?medianame=1198_en_#page=1&viewer=picture&o=bookmark&n=0&q= Accessed 16 May 2025.

Coordinating agency or organisation

World Meteorological Organization (WMO).

Preliminary – Corrections Pending

MH0306 / METEOROLOGICAL AND HYDROLOGICAL / Wind- & Pressure-Related

Depression or Cyclone (Low Pressure Area)

Definition

A depression or cyclone is a region of the atmosphere in which the pressure is lower than that of the surrounding region at the same level (WMO, 1992).

Reference

WMO, 1992. International Meteorological Vocabulary, WMO-No. 182. 2nd Edition. World Meteorological Organization (WMO). https://library.wmo.int/records/item/35809-international-meteorological-vocabulary?offset=84 Accessed 16 May 2025.

Annotations

Synonyms

Low-pressure area

Additional scientific description

A depression or cyclone is represented on a synoptic chart by a system of isobars at a specified altitude level (or a system of contours at a specified pressure level) which enclose relatively low values of pressure (or altitude) (WMO, 1992).

Metrics and numeric limits

A depression or area of low pressure generally refers to a low-pressure area with winds below storm strength of 89 km/h (WMO, 2015).

Key relevant UN convention / multilateral treaty

Not applicable.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: No Information Available

Impacts: Cyclones, including tropical and subtropical cyclones, can have far-reaching impacts, particularly in low-lying coastal areas located in the direct path of the storm. The severity of these impacts depends on the cyclone's size, intensity, and the combination of hazards such as wind speed, rainfall, storm surges, and flooding. While winds can cause significant damage, it is often the rainfall and storm surges that lead to catastrophic effects like flooding and landslides, especially in coastal and mountainous regions. Flooding can occur well ahead of landfall and persist long after, continuing to pose a risk to both lives and infrastructure, especially in densely populated or low-lying areas (UNDAC, 2024). These conditions can devastate infrastructure, disrupt communication lines, damage power grids, and result in significant casualties (UNDAC, 2024).

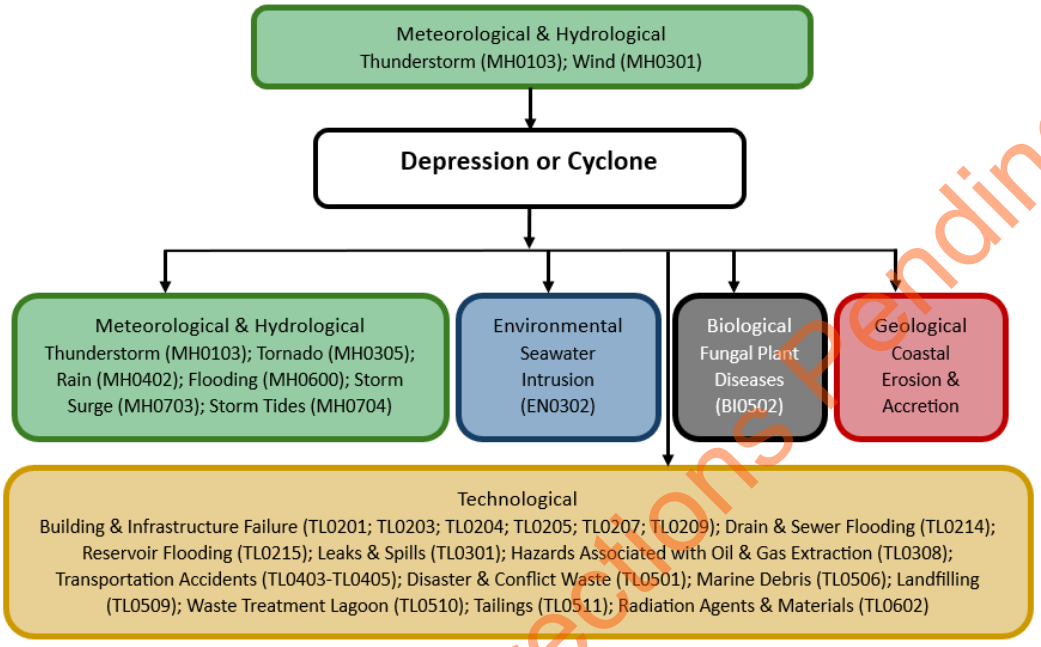
The health impacts of cyclones can be both direct and indirect, increasing the risk of drowning, physical trauma, and the spread of water- and vector-borne diseases. Floodwaters often carry sewage, chemicals, and sharp debris, which can cause injuries, diseases, and electrocution. Additionally, the disruption of public health systems during and after the cyclone limits access to essential healthcare services. Aside from physical health risks, mental health is significantly impacted, as many individuals experience stress, trauma, and anxiety in the aftermath of such disasters. Cyclone-related damage to basic infrastructure like food and water supplies and safe shelter only exacerbates these issues, increasing the risk of food insecurity and long-term health challenges (WHO, 2025; UNDAC, 2024).

The socio-economic consequences of cyclones are equally severe, as these events can cause long-term economic losses by destroying businesses, farms, and fisheries, resulting in income loss for affected families. The destruction of crops, livestock, and fisheries, along with flooding and saltwater intrusion, leads to immediate food shortages and long-term disruptions in the food supply chain. These impacts further undermine public health by increasing malnutrition and decreasing food security. Recovery is often slow,

Preliminary – Corrections Pending

as repeated cyclones can compromise agricultural land, making it harder for communities to rebuild their food stocks and livelihoods (UNDAC, 2024).

Multi-hazard Context: The figure below summarises common interactions between depressions or cyclones and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section above and the table below offer an overview of monitoring depressions or cyclones. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• Meteorological services (e.g., National Hurricane Center (NHC), Joint Typhoon Warning Center (JTWC), India Meteorological Department (IMD), Japan Meteorological Agency (JMA), and regional meteorological services) tracking low-pressure systems, wind patterns, and storm intensity. • Hydrological services monitoring rainfall, river discharge, and potential flooding associated with tropical depressions and cyclones. • National, subnational, and local disaster management agencies responsible for monitoring cyclone risks, issuing warnings, and coordinating emergency response efforts. • Geophysical and atmospheric research institutions studying atmospheric pressure variations, wind shear, and ocean-atmosphere interactions influencing storm development. • Space and remote sensing agencies (e.g., NASA, European Space Agency (ESA), and National Oceanic and Atmospheric Administration (NOAA)) using satellite technology to observe cloud formation, sea surface temperatures, and storm movement. • Maritime and naval safety authorities monitoring ocean conditions, storm surges, and issuing advisories for shipping, ports, and offshore industries. • Energy and utility companies assessing risks to power grids, oil rigs, and renewable energy infrastructure from strong winds and heavy rainfall. • Land use and urban planners integrating cyclone risk assessments into zoning laws, building codes, and disaster mitigation strategies. • Health authorities evaluating public health risks, including disease outbreaks, injuries, and emergency medical response needs due to cyclonic impacts. • Researchers and academics, including climatologists and meteorologists, studying tropical cyclone formation, climate change impacts, and forecasting improvements. • Environmental organisations and conservation groups advocating for coastal resilience, mangrove conservation, and sustainable disaster risk management. • Coastal and inland communities engaged in early warning dissemination, evacuation planning, and resilience-building efforts against tropical depressions and cyclones.

Preliminary – Corrections Pending

How is the Hazard Observed/Monitored/Forecast?	Depressions and cyclones (low-pressure areas) are monitored using weather satellites, radar, and ocean buoys to track wind speeds, air pressure, and storm movement. Meteorologists analyse sea surface temperatures, atmospheric conditions, and wind patterns to predict storm development. Advanced computer models simulate storm paths and intensity, helping forecasters issue early warnings. These alerts enable communities, emergency responders, and industries to prepare for heavy rainfall, strong winds, and potential flooding.

Risk Management: A depression, also known as a cyclone or low-pressure area, is a region with lower atmospheric pressure than the surrounding areas. These systems are characterised by rising air, which leads to cloud formation and often results in unsettled weather conditions, including heavy rainfall, strong winds, and storm surge. The unpredictable nature of these weather patterns underscores the importance of multi-hazard early warning systems (MHEWS). MHEWS integrates various tools and technologies to monitor and predict multiple hazards, ensuring the timely dissemination of warnings to vulnerable communities. By leveraging advanced forecasting models, real-time data, and effective communication strategies, MHEWS enhances preparedness and response actions, thereby mitigating the adverse impacts associated with depressions and other related weather phenomena (WMO, 2025).

References

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Coordinating agency or organisation

World Meteorological Organization (WMO).

Preliminary – Corrections Pending

MH0307 / METEOROLOGICAL AND HYDROLOGICAL / Wind- & Pressure-related

Extra-tropical Cyclone

Definition

An extra-tropical cyclone is a low-pressure system, which develops in latitudes outside the tropics (WMO, 1992).

Reference

WMO, 1992. International Meteorological Vocabulary, WMO-No. 182. 2nd Edition. World Meteorological Organization (WMO). https://library.wmo.int/records/item/35809-international-meteorological-vocabulary?offset=2 Accessed 16 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Mid-latitude storm, Baroclinic storm.

Additional scientific description

An extra-tropical cyclone is a storm system that primarily gets its energy from the horizontal temperature contrasts that exist in the atmosphere. Extra-tropical cyclones (also known as mid-latitude or baroclinic storms) are low-pressure systems with associated cold fronts, warm fronts, and occluded fronts. In contrast, tropical cyclones typically have little to no temperature differences across the storm at the Earth's surface and their winds are derived from the release of energy due to cloud/rain formation from the warm, moist air of the tropics (NASA, 2020).

Notes for clarification: Differences between an extra-tropical cyclone and a tropical cyclone:

- An extra-tropical cyclone is a low-pressure system that primarily gets its energy from the temperature difference in the horizontal direction across the cyclone (known as temperature gradient in meteorology). Structurally, tropical cyclones have their strongest winds near the Earth's surface, while extra-tropical cyclones have their strongest winds near the tropopause – about 8 miles (12 km) up. These differences are due to the tropical cyclone being 'warm-core' in the troposphere (below the tropopause) and the extra-tropical cyclone being 'warm-core' in the stratosphere (above the tropopause) and 'cold-core' in the troposphere. 'Warm-core' refers to being relatively warmer than the environment at the same pressure surface ('pressure surfaces' are simply another way to measure height or altitude).
- A tropical cyclone will often transform into an extra-tropical cyclone as it recurves poleward and to the east. Occasionally, an extra-tropical cyclone will lose its frontal features, develop convection near the centre of the storm and transform into a full-fledged tropical cyclone. Such a process is most common in the North Atlantic and Northwest Pacific basins. The transformation of a tropical cyclone into an extra-tropical cyclone (and vice versa) is currently one of the most challenging forecasting problems (NOAA, 2004; Hong Kong Observatory, 2019).

Extra-tropical cyclones are large rotating weather systems that occur in the extra-tropics (generally more than 30° latitude away from the equator). They consist of an approximately circular region of low surface pressure, of a radius of 100-2000 km, accompanied by cold and warm fronts. They typically develop in regions of strong horizontal temperature gradients, which are commonly denoted on a weather chart as a cold or quasi-stationary front. In turn, such fronts often connect to a pre-existing decaying extra-tropical cyclone, which itself is situated some way downstream (typically to the north-east) (CCPO, no date).

At the same time, high up in the atmosphere (around 10 km altitude), a jet stream is typically found relatively close by. In fact, the intensity of an extra-tropical cyclone is closely related to the strength of this jet stream. The strongest extra-tropical cyclones occur in the winter months when the jet stream is at its strongest. Periods when the jet stream is unusually strong can lead to two or more strong cyclones occurring within days of each other. The total lifecycle of an extra-tropical cyclone from birth (genesis) through to development and on to decay (lysis) can occasionally be more than 10 days, although somewhere in the range of 2 to 5 days is more typical (Frame et al., 2017).

Metrics and numeric limits

Not available.

Key relevant UN convention / multilateral treaty

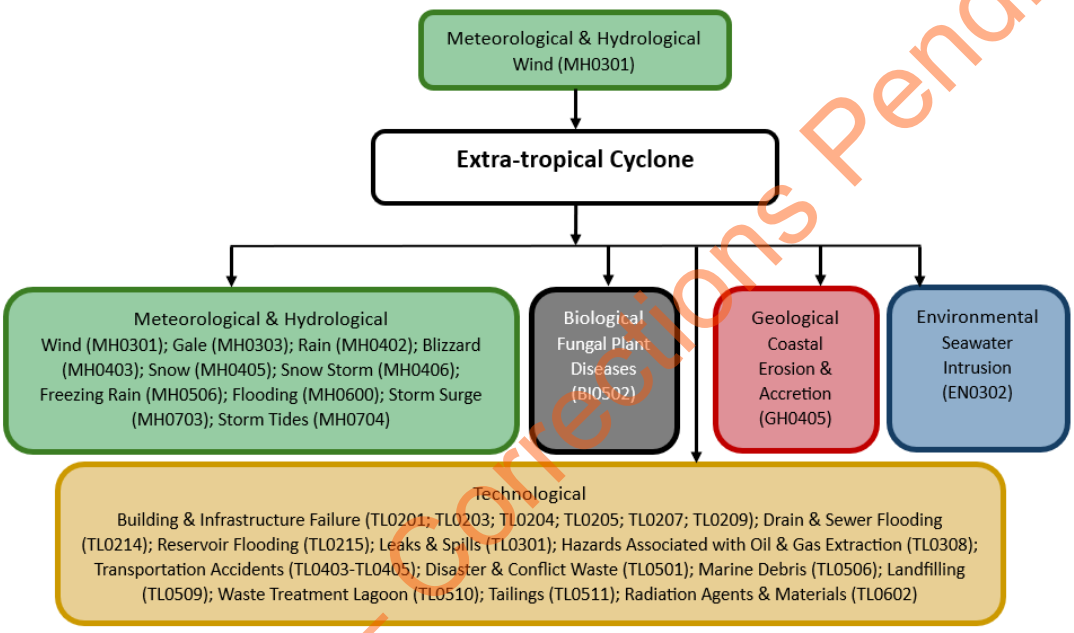
Not available.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: No Available Information

Impacts: The major hazards associated with extra-tropical cyclones are high winds and precipitation (rain and snow). Precipitation occurs primarily along fronts and, on average, is not particularly intense relative to that delivered by tropical cyclones and convective storms (Frame et al., 2017).

Multi-hazard Context: The figure below summarises common interactions between extra-tropical cyclones and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section above and the table below offer an overview of monitoring extra-tropical cyclones. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• National, subnational, and local disaster management agencies responsible for monitoring extra-tropical cyclone risks, issuing warnings, and coordinating emergency response efforts. • Meteorological services tracking extra-tropical cyclone formation, wind patterns, and storm intensity and issuance of relevant warnings (when under their mandate). • Hydrological services monitoring rainfall, river discharge, and potential flooding associated with extra-tropical cyclones and issuance of relevant warnings when under their mandate. • Space and remote sensing agencies (e.g., NASA, European Space Agency (ESA), National Oceanic and Atmospheric Administration (NOAA)) using satellite technology to observe cloud formation, sea surface temperatures, and cyclone movement. • Maritime and naval safety authorities monitoring ocean conditions, storm surges, and issuing advisories for shipping, ports, and offshore industries. • Energy and utility companies assessing risks to power grids, oil rigs, and renewable energy infrastructure from strong winds and heavy rainfall. • Land use and urban planners integrating extra-tropical cyclone risk assessments into zoning laws, building codes, and disaster mitigation strategies. • Health authorities evaluating public health risks, including disease outbreaks, injuries, and emergency medical response needs due to storm impacts. • Researchers and academics, including meteorologists and climate scientists, studying extra-tropical cyclone formation, climate change impacts, and forecasting improvements.

Preliminary – Corrections Pending

	• Environmental organisations and conservation groups advocating for coastal resilience, wetland conservation, and sustainable disaster risk management. • Coastal and inland communities engaged in early warning dissemination, evacuation planning, and resilience-building efforts against extra-tropical cyclones.
How is the Hazard Observed/Monitored/Forecast?	Extra-tropical cyclones are monitored using technologies such as satellites, radar, and weather balloons to track wind speeds, air pressure, and storm movement. Meteorologists analyse temperature contrasts, wind patterns, and ocean conditions to predict storm development and intensity. Advanced computer models simulate storm paths, helping forecasters issue early alerts and warnings. These alerts and warnings assist communities, emergency responders, and industries to prepare for hazards such as heavy rain, snow, strong winds, and flooding.

Risk Management: No Information Available.

References

Center for Coastal Physical Oceanography (CCPO), no date. Horizontal Structure of Atmosphere. Chapter 2. [online] Available at: http://www.ccpo.odu.edu/SEES/ozone/class/Chap_2/2_4.htm Accessed 16 May 2025.

Frame, T., Harrison, G., Hewson, T. and Roberts, N., 2017. Meteorological risk: extra-tropical cyclones, tropical cyclones and convective storms. In: Science for Disaster Risk Management, pp.246-256. [online] Available at: https://drmkc.jrc.ec.europa.eu/portals/0/Knowledge/ScienceforDRM/ch03_s03/ch03_s03_subch0307.pdf Accessed 16 May 2025.

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National Oceanic and Atmospheric Administration (NOAA), 2004. What is an Extra-tropical Cyclone? Atlantic Oceanographic & Meteorological Laboratory, [online] Available at: https://www.nhc.noaa.gov/outreach/presentations/NHC2017_WhatIsATC.pdf Accessed 16 May 2025.

Coordinating agency or organisation

World Meteorological Organization (WMO).

Preliminary – Corrections Pending

MH0308 / METEOROLOGICAL AND HYDROLOGICAL / Wind- & Pressure-related

Subtropical Cyclone

Definition

A subtropical cyclone is a non-frontal, low-pressure system that has characteristics of both tropical and extra-tropical cyclones. Like tropical cyclones, they are non-frontal, synoptic-scale cyclones that originate over tropical or subtropical waters and have a closed surface wind circulation about a well-defined centre (WMO, 2024 a).

Reference

WMO, 2024 a. Regional Association IV - Hurricane Operational Plan for North America, Central America and the Caribbean. Tropical Cyclone Programme, Report No. TCP-30, World Meteorological Organization (WMO). Regional Association IV - Hurricane Operational Plan Accessed 03 February 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Not identified.

Additional scientific description

A subtropical cyclone is a non-frontal, low-pressure system developing over tropical or subtropical waters which initially contains few tropical characteristics. With time, the subtropical cyclone can become a tropical cyclone (WMO, 2024 b).

Subtropical cyclones have organised moderate to deep convection but lack a central dense overcast. Unlike tropical cyclones, subtropical cyclones derive a significant proportion of their energy from baroclinic sources and are generally cold-core in the upper troposphere, often being associated with an upper-level low or trough. In comparison to tropical cyclones, these systems generally have a radius of maximum winds occurring relatively far from the centre (usually greater than 60 nautical miles) and generally have a less symmetric wind field and distribution of convection (WMO, 2024 a; NOAA, 2019).

Subtropical storm: A subtropical storm is a subtropical cyclone in which the maximum sustained surface wind speed (using the U.S. 1-minute average) is 34 kt (39 mph or 63 km/hr) or more (NOAA, 2019).

Subtropical depression: A subtropical cyclone in which the maximum sustained surface wind speed (using the U.S. 1-minute average) is 33 kt (38 mph or 62 km/hr) or less (NOAA, 2019).

Metrics and numeric limits

Not applicable.

Key relevant UN convention / multilateral treaty

Not applicable.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: No Information Available.

Impacts: Cyclones, including tropical and subtropical cyclones, can have far-reaching impacts, particularly in low-lying coastal areas located in the direct path of the storm. The severity of these impacts depends on the cyclone's size, intensity, and the combination of hazards such as wind speed, rainfall, storm surges, and flooding. While winds can cause significant damage, it is often the rainfall and storm surges that lead to catastrophic effects like flooding and landslides, especially in coastal and mountainous regions. Flooding can occur well ahead of landfall and persist long after, continuing to pose a risk to both lives and infrastructure, especially in densely

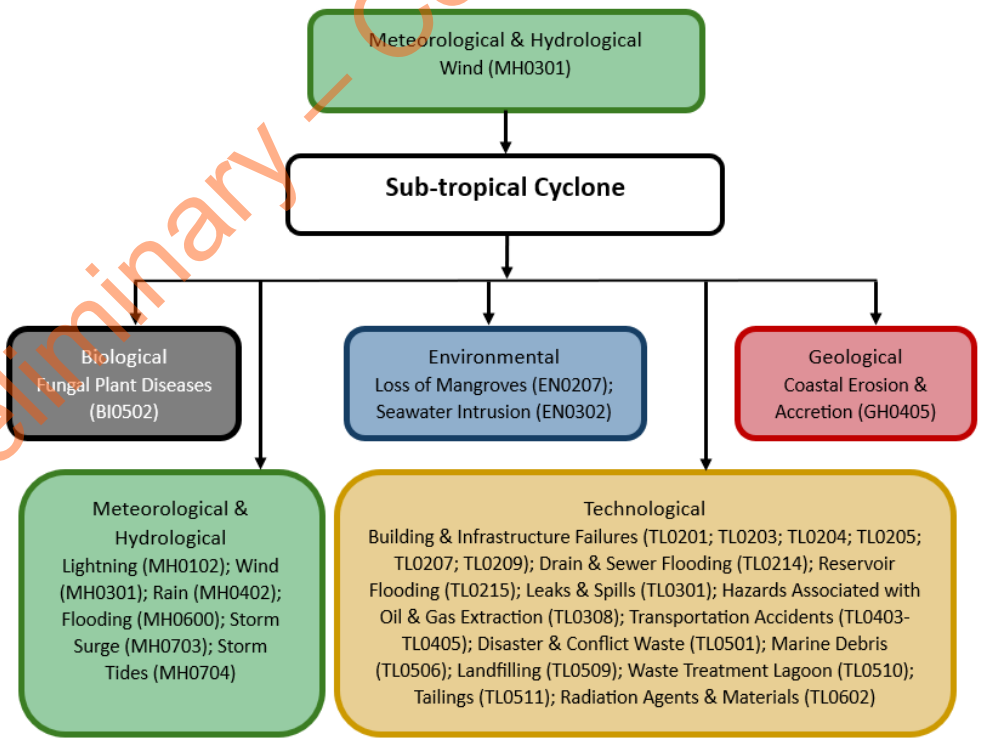
populated or low-lying areas (UNDAC, 2024). These conditions can devastate infrastructure, disrupt communication lines, damage power grids, and result in significant casualties (UNDAC, 2024).

The health impacts of cyclones can be both direct and indirect, increasing the risk of drowning, physical trauma, and the spread of water- and vector-borne diseases. Floodwaters often carry sewage, chemicals, and sharp debris, which can cause injuries, diseases, and electrocution. Additionally, the disruption of public health systems during and after the cyclone limits access to essential healthcare services. Aside from physical health risks, mental health is significantly impacted, as many individuals experience stress, trauma, and anxiety in the aftermath of such disasters. Cyclone-related damage to basic infrastructure like food and water supplies and safe shelter only exacerbates these issues, increasing the risk of food insecurity and long-term health challenges (WHO, 2025; UNDAC, 2024).

The socio-economic consequences of cyclones are equally severe, as these events can cause long-term economic losses by destroying businesses, farms, and fisheries, resulting in income loss for affected families. The destruction of crops, livestock, and fisheries, along with flooding and saltwater intrusion, leads to immediate food shortages and long-term disruptions in the food supply chain. These impacts further undermine public health by increasing malnutrition and decreasing food security. Recovery is often slow, as repeated cyclones can compromise agricultural land, making it harder for communities to rebuild their food stocks and livelihoods (UNDAC, 2024).

Subtropical cyclones, exhibiting both tropical and extra-tropical characteristics, present unique challenges for early warning systems (EWS). Their hybrid nature can lead to rapid intensification and unpredictable paths, complicating accurate forecasting. To address these challenges, advanced numerical weather prediction models, satellite observations, and Doppler radar are employed to monitor their development. National Meteorological and Hydrological Services (NMHSs) play a pivotal role in issuing timely warnings based on real-time data, ensuring that vulnerable populations receive prompt alerts. An effective EWS comprises four key elements: disaster risk knowledge, detection, monitoring, analysis and forecasting, warning dissemination and communication, and preparedness and response capabilities. Integrated EWS frameworks that encompass these elements are essential to mitigate potential damages, particularly in coastal regions prone to high winds, heavy rainfall, and flooding from subtropical storms (WMO, 2025).

Multi-hazard Context: The figure below summarises common interactions between subtropical cyclones and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section above and the table below offer an overview of monitoring subtropical cyclones. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Preliminary - Corrections Pending

Which institution(s) produce(s) Disaster Risk Data/Information?	• National, subnational, and local disaster management agencies responsible for monitoring subtropical cyclone risks, issuing warnings, and coordinating emergency response efforts. • Meteorological services (e.g., National Hurricane Center (NHC), Joint Typhoon Warning Center (JTWC), Japan Meteorological Agency (JMA), India Meteorological Department (IMD), and regional meteorological services) tracking subtropical cyclone formation, wind patterns, and storm intensity. • Hydrological services monitoring rainfall, river discharge, and potential flooding associated with subtropical cyclones. • Space and remote sensing agencies (e.g., NASA, European Space Agency (ESA), National Oceanic and Atmospheric Administration (NOAA)) using satellite technology to observe cloud formation, sea surface temperatures, and cyclone movement. • Maritime and naval safety authorities monitoring ocean conditions, storm surges, and issuing advisories for shipping, ports, and offshore industries. • Energy and utility companies assessing risks to power grids, oil rigs, and renewable energy infrastructure from strong winds and heavy rainfall. • Land use and urban planners integrating subtropical cyclone risk assessments into zoning laws, building codes, and disaster mitigation strategies. • Health authorities evaluating public health risks, including disease outbreaks, injuries, and emergency medical response needs due to storm impacts. • Researchers and academics, including meteorologists and climate scientists, studying subtropical cyclone formation, climate change impacts, and forecasting improvements. • Environmental organisations and conservation groups advocating for coastal resilience, wetland conservation, and sustainable disaster risk management. • Coastal and inland communities engaged in early warning dissemination, evacuation planning, and resilience-building efforts against subtropical cyclones.
How is the Hazard Observed/Monitored/Forecast?	Subtropical cyclones are monitored using satellites, weather radar, specialised scientific aircraft, and ocean buoys to track wind speeds, air pressure, and storm movement. Meteorologists analyse sea surface temperatures, atmospheric instability, and jet stream interactions to predict storm development. Advanced computer models simulate storm paths and intensity, helping forecasters issue early warnings. These alerts assist coastal communities, emergency responders, and maritime industries in preparing for heavy rain, strong winds, and potential flooding.

Risk Management: Tropical Cyclone Operational Plans are updated on an annual basis, and therefore definitions within the Operational Plans are subject to possible revision (available here: https://community.wmo.int/en/tropical-cyclone-operational-plans).

References

National Hurricane Center (NHC) and Central Pacific Hurricane Center, National Oceanic and Atmospheric Administration (NOAA), 2019. Glossary of NHC Terms. [online] Available at: https://www.nhc.noaa.gov/aboutgloss.shtml Accessed 16 May 2025.

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Coordinating agency or organisation

World Meteorological Organization (WMO).

Preliminary – Corrections Pending

MH0309 / METEOROLOGICAL AND HYDROLOGICAL / Wind- & Pressure-related

Tropical Cyclone

Definition

A tropical cyclone is a cyclone of tropical origin of small diameter (some hundreds of kilometres) with a minimum surface pressure in some cases of less than 900 hPa, very violent winds and torrential rain; sometimes accompanied by thunderstorms. It usually contains a central region, known as the 'eye' of the storm, with a diameter of the order of some tens of kilometres, and with light winds and a more or less lightly clouded sky (WMO, 2023).

Alternative definition: A tropical cyclone is a warm-core, non-frontal synoptic-scale cyclone, originating over tropical or subtropical waters, with organised deep convection and closed surface wind circulation about a well-defined centre (WMO, 2024).

Preliminary – Corrections Pending

References

WMO, 2023. Manual on Codes, International Codes, Volume I.2, WMO-No. 306. World Meteorological Organization (WMO). https://library.wmo.int/records/item/35625-manual-on-codes-international-codes-volume-i-2 Accessed 16 May 2025.

WMO, 2024. Regional Association IV - Hurricane Operational Plan for North America, Central America and the Caribbean. Tropical Cyclone Programme. Report No. TCP-30. RA IV - Hurricane Operational Plan Tropical Cyclone Operational Plans | World Meteorological Organization

Annotations

Synonyms

Typhoon, Hurricane, Cyclone, Severe tropical cyclone.

Note: Typhoon, hurricane, cyclone, and tropical cyclone are different terms for the same weather phenomenon in different geographical regions (WMO, 2023):

- In the western North Atlantic, central and eastern North Pacific, Caribbean Sea and Gulf of Mexico, such a weather phenomenon is called a 'hurricane'.
- In the western North Pacific, it is called a 'typhoon'.
- In the Bay of Bengal and Arabian Sea, it is called a 'cyclone'.
- In the western South Pacific and southeast Indian Ocean, it is called a 'severe tropical cyclone'.
- In the southwest India Ocean, it is called a 'tropical cyclone'.

Additional scientific description

A tropical cyclone is a rapidly rotating storm that begins over tropical oceans, and it can vary in speed, size, and intensity (WMO, 2025).

The typhoon season in the western North Pacific region typically runs from May to November. The Americas/Caribbean hurricane season runs from 1 June to 30 November, peaking in August and September. The cyclone season in the South Pacific and

Australia normally runs from November to April. In the Bay of Bengal and Arabian Sea, tropical cyclones usually occur from April to June and from September to November. The East Coast of Africa normally experiences tropical cyclones from November to April (WMO, 2023).

Metrics and numeric limits

Tropical cyclones above a particular wind speed are classified for public safety.
Depending on the maximum sustained wind speed, tropical cyclones are designated as follows:

- Tropical depression is when the maximum sustained wind speed is less than 63 km/h.
- Tropical storm is when the maximum sustained wind speed is more than 63 km/h. It is then also given a name.
- Hurricane, typhoon, tropical cyclone, very severe cyclonic storm - depending on the basin - when the maximum sustained wind speed exceeds 116 km/h or 63 knots.

The table below provides more detail on tropical cyclone classifications and development thresholds in the five Tropical Cyclone Committees (WMO, 2023).

knot	km/h	Beaufort	South West Indian Ocean*	Arabian Sea and Bay of Bengal**	North West Pacific**	North Atlantic and North East Pacific***	South West Pacific and South East Indian Ocean*
Average wind speed			knot km/h	knot km/h		Knot km/h mi/h	knot km/h
			Zone of disturbed weather	Low pressure area			Tropical disturbance
17 27	31 50	6	Tropical disturbance	Depression	Tropical depression	Tropical depression	Tropical low/depression
28 33	51 62	7	Tropical depression	Deep depression			
34 40 47	63 88	8 9	Moderate tropical storm	Cyclonic storm	Tropical storm	34 39 Tropical storm	Tropical cyclone (gale) / Category 1
48 52 63	89 117	10 11	Severe tropical storm	Severe cyclonic storm	Severe tropical storm	73	Tropical cyclone (storm) / Category 2
64	118	12	64 Tropical cyclone	64 Very Severe Cyclonic Storm	Typhoon	64 Hurricane CAT 1 82 153 95	64 Severe tropical cyclone (hurricane) / Category 3
						83 154 96 Hurricane CAT 2 95 177 110	
			89 165	89 166		96 178 111 Hurricane CAT 3 112 208 129	85 159
			90 166 Intense tropical cyclone 115 212	90 167 Extremely Severe Cyclonic Storm 119 221		113 209 130 Hurricane CAT 4 136 251 156	86 160 Tropical cyclone / Category 4 107 199
			116 213 Very intense tropical cyclone	120 222 Super cyclonic storm		137 252 157 Hurricane CAT 5	>107 >200 Tropical Cyclone / Category 5

Key relevant UN convention / multilateral treaty

Not identified.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: No Information Available

Impacts: Tropical cyclones can have far-reaching impacts, particularly in low-lying coastal areas located in the direct path of the storm. The severity of these impacts depends on the cyclone's size, intensity, and the combination of hazards such as wind speed, rainfall, storm surges, and flooding. While winds can cause significant damage, it is often the rainfall and storm surges that lead to catastrophic effects like flooding and landslides, especially in coastal and mountainous regions. Flooding can occur well ahead of landfall and persist long after, continuing to pose a risk to both lives and infrastructure, especially in densely populated or low-lying areas (UNDAC, 2024). These conditions can devastate infrastructure, disrupt communication lines, damage power grids, and result in significant casualties (UNDAC, 2024).

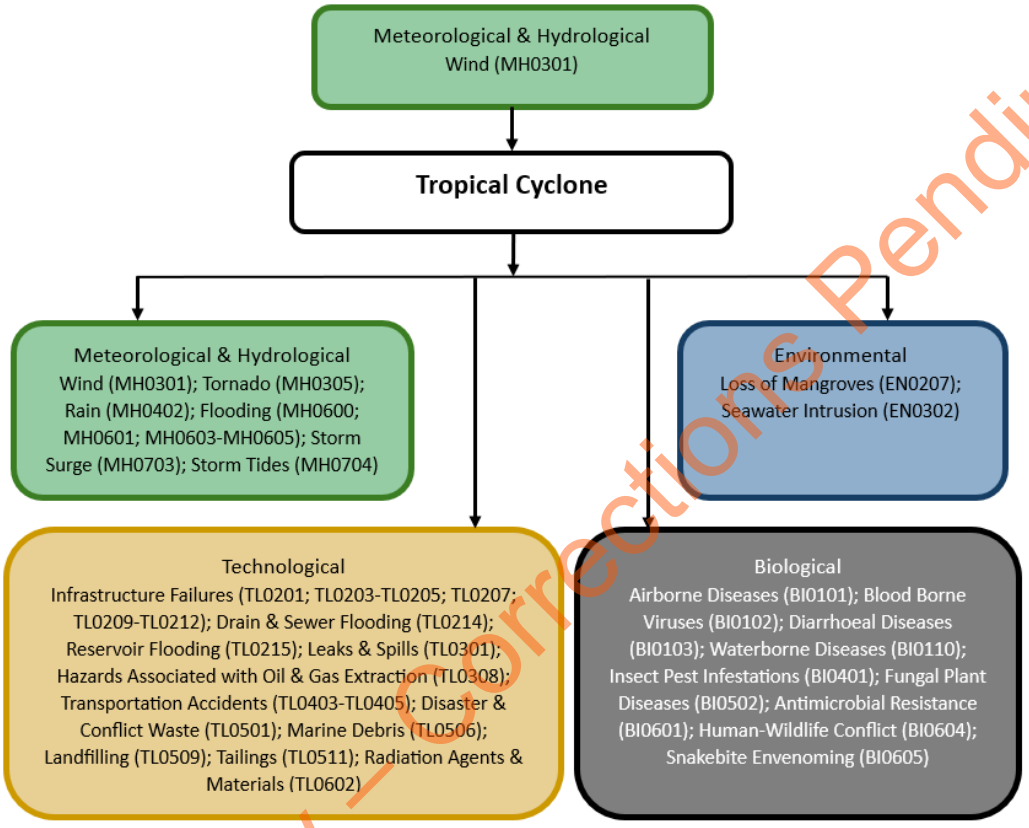
The health impacts of tropical cyclones can be both direct and indirect, increasing the risk of drowning, physical trauma, and the spread of water- and vector-borne diseases. Floodwaters often carry sewage, chemicals, and sharp debris, which can cause injuries, diseases, and electrocution. Additionally, the disruption of public health systems during and after the cyclone limits access to essential healthcare services. Aside from physical health risks, mental health is significantly impacted, as many individuals experience stress, trauma, and anxiety in the aftermath of such disasters. Cyclone-related damage to basic infrastructure like food and water supplies and safe shelter only exacerbates these issues, increasing the risk of food insecurity and long-term health challenges (WHO, 2025; UNDAC, 2024).

The socio-economic consequences of tropical cyclones are equally severe, as these events can cause long-term economic losses by destroying businesses, farms, and fisheries, resulting in income loss for affected families. The destruction of crops, livestock, and

Preliminary – Corrections Pending

fisheries, along with flooding and saltwater intrusion, leads to immediate food shortages and long-term disruptions in the food supply chain. These impacts further undermine public health by increasing malnutrition and decreasing food security. Recovery is often slow, as repeated cyclones can compromise agricultural land, making it harder for communities to rebuild their food stocks and livelihoods (UNDAC, 2024).

Multi-hazard Context: The figure below summarises common interactions between tropical cyclones and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section above and the table below offer an overview of monitoring tropical cyclones. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• National, subnational, and local disaster management agencies responsible for monitoring tropical cyclones, issuing warnings, and coordinating emergency response efforts. • Meteorological services tracking cyclone formation, wind speeds, and storm intensity using specialised scientific aircraft, satellites, radar, to track cyclone movement, cloud cover, and storm strength. • WMO Regional Specialized Meteorological Centers (RSMCs) (e.g., RSMC Miami (NHC), RSMC Tokyo (JMA), RSMC New Delhi (IMD), RSMC La Réunion (Météo-France), RSMC Nadi (Fiji Meteorological Service)) providing cyclone forecasts and guidance. • Hydrological services monitoring rainfall accumulation, river discharge, storm surge risks, and potential flooding caused by tropical cyclones. • Maritime and naval safety authorities monitoring sea conditions, wave heights, and issuing advisories for shipping, ports, and offshore industries due to cyclonic storms. • Transportation and infrastructure agencies assessing risks to roads, bridges, airports, and railways from extreme winds, flooding, and storm surges. • Energy and utility companies monitoring risks to power grids, offshore oil rigs, and renewable energy infrastructure from high winds and flooding. • Health authorities evaluating public safety risks, including injuries, disease outbreaks, and emergency medical response needs after cyclone impacts. • Researchers and academics, including meteorologists, climatologists, and disaster risk scientists, studying tropical cyclone formation, predictive modelling, and resilience strategies.

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	• Environmental organisations and conservation groups advocating for coastal protection, mangrove restoration, and climate adaptation strategies to mitigate cyclone damage. • Community organisations and local governments engaged in early warning dissemination, evacuation planning, and public awareness campaigns in cyclone-prone regions.
How is the Hazard Observed/Monitored/Forecast?	Tropical cyclones are monitored using satellites, weather radar, ocean buoys, and specialised reconnaissance aircraft to track their development and progression. Meteorologists analyse sea surface temperatures, atmospheric pressure, and wind patterns and use advanced weather models combined with real-time observational data to forecast storm intensity and path. These forecasts enable timely warnings to be issued, helping coastal communities, emergency responders, and infrastructure managers prepare for hazards such as destructive winds, heavy rainfall, storm surges, and flooding.

Risk Management: Meteorologists around the world use modern technology such as satellites, weather radars and computers etc. to track tropical cyclones as they develop. Tropical cyclones are often difficult to predict because they can suddenly weaken or change their course. However, meteorologists use state-of-the-art technologies and develop modern techniques such as numerical weather prediction models to predict how a tropical cyclone evolves, including its movement and change of intensity, when and where one will hit land and at what speed. Official warnings are then issued by the National Meteorological Services of the countries concerned (WMO, 2023).

Tropical cyclones may damage infrastructure, including power lines, leading to power outages that can lead to electrocution, fires and burns and carbon monoxide poisoning from gasoline-powered electrical generators.

The World Health Organization (WHO) works with Member States to build resilient and proactive health systems that can anticipate the needs and challenges during emergencies so that they are more likely to reduce risks and respond effectively when needed. During disasters, such as tropical cyclones, the WHO helps to restore primary care services so that facilities can deliver essential services, including immunisation, basic treatment for common illnesses, acute malnutrition and maternal care, while ensuring the ongoing supply of medications for people living with HIV, tuberculosis or diabetes. As the health cluster lead for global emergencies, the WHO also works with partners to ensure appropriate food supplementation; to assemble mobile health teams and outreach; to conduct epidemic surveillance, early warning and response; and to call for emergency funding to support health action (WHO, 2025).

The World Meteorological Organization (WMO) framework allows the timely and widespread dissemination of information about tropical cyclones. As a result of international cooperation and coordination, tropical cyclones are increasingly being monitored from their early stages of formation. The activities are coordinated at the global and regional level by the WMO through its World Weather Watch and Tropical Cyclone Programmes. The Regional Specialised Meteorological Centres with the activity specialisation in tropical cyclones, and Tropical Cyclone Warning Centres, all designated by the WMO, function within its Tropical Cyclone Programme. Their role is to detect, monitor, track and forecast all tropical cyclones in their respective regions. The Centres provide, in real-time, advisory information and guidance to the National Meteorological Services (WMO, 2023).

Preliminary – Corrections Pending

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Coordinating agency or organisation

World Meteorological Organization (WMO).

MH0401 / METEOROLOGICAL AND HYDROLOGICAL / Precipitation-related

Drought

Definition

A drought is a period of abnormally dry weather characterised by a prolonged deficiency of precipitation below a certain threshold over a large area and a period longer than a month (WMO, 2023).

Reference

WMO, 2023. Guidelines on the Definition and Characterization of Extreme Weather and Climate Events. World Meteorological Organization (WMO) https://library.wmo.int/records/item/58396-guidelines-on-the-definition-and-characterization-of-extreme-weather-and-climate-events?offset=1 Accessed 16 May 2025.

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Annotations

Synonyms

None identified

Additional scientific description

Drought is described as conditions that are significantly drier than normal or otherwise limiting moisture availability to a potentially damaging extent (WMO and GWP, 2016) or as conditions where there has been a prolonged absence or marked deficiency of precipitation (WMO/UNESCO, 2012).

Whereas drought may be defined simply as the absence of water, it is a complex phenomenon which is monitored over a number of time scales and often defined according to need. It is a slow-onset phenomenon that gradually intensifies and can impact many sectors of the economy and the environment.

Droughts can be characterised in terms of their severity, location, duration and timing. Droughts can arise from a range of hydrometeorological processes that suppress precipitation and/or limit surface water or groundwater availability. There are various drought indicators and indices that provide options for identifying the severity, location, duration, onset and cessation of such conditions. It is important to note that the impacts of drought can be as varied as the causes of drought. Droughts can adversely affect agriculture and food security, hydropower generation and industry, human and animal health, livelihood security, and personal security and access to education. Such impacts depend on the socio-economic contexts in which droughts occur, in terms of who or what is exposed to the droughts and the specific vulnerabilities of the exposed entities (WMO and GWP, 2016).

The drought community has defined several different types of drought that can have general or specific sector impacts (NOAA, no date b):

- *Meteorological drought*: Occurs when dry weather patterns dominate an area. It is defined usually on the basis of the degree of dryness and the duration of the dry period.
- *Hydrological drought*: Occurs when low water supply becomes evident and is associated with the effects of periods of precipitation shortfalls on surface or subsurface water supply.
- *Agricultural drought*: Occurs when agricultural production is affected. It focuses on precipitation shortages, differences between actual evapotranspiration, soil water deficits, reduced groundwater and so on.
- *Socioeconomic drought*: Relates the supply and demand of some economic goods with elements of meteorological, hydrological, and agricultural drought. It also occurs when the demand for an economic good exceeds supply as a result of a weather-related shortfall in water supply.

Metrics and numeric limits

Specific indices have been created to assess drought. For example, the Palmer Drought Index and Standardized Precipitation Index (SPI), and advanced complex models (such as the National Land Data Assimilation System [NLDAS] or the Combined Drought Indicator in Europe) (European Drought Observatory, 2019), which calculate soil moisture and other hydrological

variables. There are also indices used for water supply forecasting (such as the Surface Water Supply Index [SWSI]), and indices which reflect impacts on vegetation (such as the Vegetation Health Index [VHI] and Vegetation Drought Response Index [VegDRI]) (NOAA, no date c).

Indicators are variables or parameters used to describe drought conditions, and these include precipitation, temperature, streamflow, groundwater and reservoir levels, soil moisture and snowpack. Indices are typically computed numerical representations of drought severity, assessed using climatic or hydrometeorological inputs. They aim to measure the qualitative state of droughts on the landscape for a given time period. Indices can simplify complex relationships and provide useful communication tools for diverse audiences and users, including the public. Indices are used to provide a quantitative assessment of the severity, location, timing and duration of drought events. Severity refers to the departure from normal of an index. A threshold for severity may be set to determine when a drought has begun, when it ends, and the geographic area affected. Location refers to the geographic area experiencing drought conditions. The timing and duration are determined by the approximate dates of onset and cessation (WMO and GWP, 2016).

The World Meteorological Organization (WMO)'s Handbook of Drought Indicators and Indices provides a compendium of the most commonly used drought indicators/indices that are being applied across drought-prone regions. The indices are grouped under: meteorology (23 indices); soil moisture (4 indices); hydrology (8 indices); remote sensing (10 indices); and composite or modelled (5 indices). Each index is elaborated in detail with its origin, characteristics, input parameters, application, strengths, weaknesses, resources, and references (WMO and GWP, 2016). The Handbook includes many commonly used drought indicators/indices, such as several versions of the Palmer Drought Indices and the Keetch-Byram Drought Index.

The Standardized Precipitation Index (SPI) is an index that considers only precipitation, and it is easy to use. A period of record of at least 30 years of data is recommended, and a shorter period should only be used with caution. The SPI can be very useful when the amount of data for calculations is limited. It is easier to communicate in some situations than in other, more complex indices, as it is only based on rainfall received and a comparison with historical rainfall amounts. The SPI is an index based on the probability of receiving a given amount of precipitation, and the probabilities are standardised such that an index of zero indicates the median precipitation amount (half of the historical precipitation amounts are below the median, and half are above the median). The index is negative for drought and positive for wet conditions. The SPI can be computed from one month to 24 months, to capture both short-term and long-term conditions (WMO, 2012; NOAA, no date c). In June 2011, the Sixteenth World Meteorological Congress adopted a resolution that recommended that the SPI be used by all National Meteorological and Hydrological Services (NMHSs) around the world to characterise meteorological droughts, in addition to other drought indices that were in use in their service.

Key relevant UN convention / multilateral treaty

The United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, particularly in Africa (UNCCD, 1994). Established in 1994, the United Nations Convention to Combat Desertification (UNCCD) is the sole legally binding international agreement linking the environment and development to sustainable land management. The Convention addresses specifically the arid, semi-arid and dry sub-humid areas, known as the drylands, where some of the most vulnerable ecosystems and peoples can be found (UNCCD, 2017).

This is the most comprehensive global commitment to achieve Land Degradation Neutrality (LDN) in order to restore the productivity of vast expanses of degraded land, improve the livelihoods of more than 1.3 billion people, and reduce the impacts of drought on vulnerable populations.

The United Nations Watercourses Convention (United Nations, 1997), entered into force on 17 August 2014.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Drought is associated with heatwaves and limited or no rain.

Impacts: Drought can have a serious impact on health, agriculture, economies, energy and the environment. An estimated 55 million people globally are affected by droughts every year, and they are the most serious hazard to livestock and crops in nearly every part of the world. Drought threatens people's livelihoods, increases the risk of disease and death, and drives mass migration. Water scarcity impacts 40% of the world's population, and as many as 700 million people are at risk of being displaced as a result of drought by 2030 (WHO, 2025).

The probability of drought-related health impacts varies widely and largely depends upon drought severity, baseline population vulnerability, existing health and sanitation infrastructure, and available resources with which to mitigate impacts as they occur (Stanke et al., 2013). When drought causes water and food shortages, there can be many impacts on the health of the affected population, which may increase the risk of disease and death. Drought may have acute and chronic health effects, including: malnutrition due to the decreased availability of food, including micronutrient deficiency (such as iron-deficiency anaemia); increased risk of infectious diseases (such as cholera, diarrhoea, and pneumonia), due to acute malnutrition, lack of water and sanitation, and displacement; psycho-social stress and mental health disorders; and disruption of local health services due to a lack of water supplies, loss of buying power, migration and/or health workers being forced to leave local areas. Severe drought can

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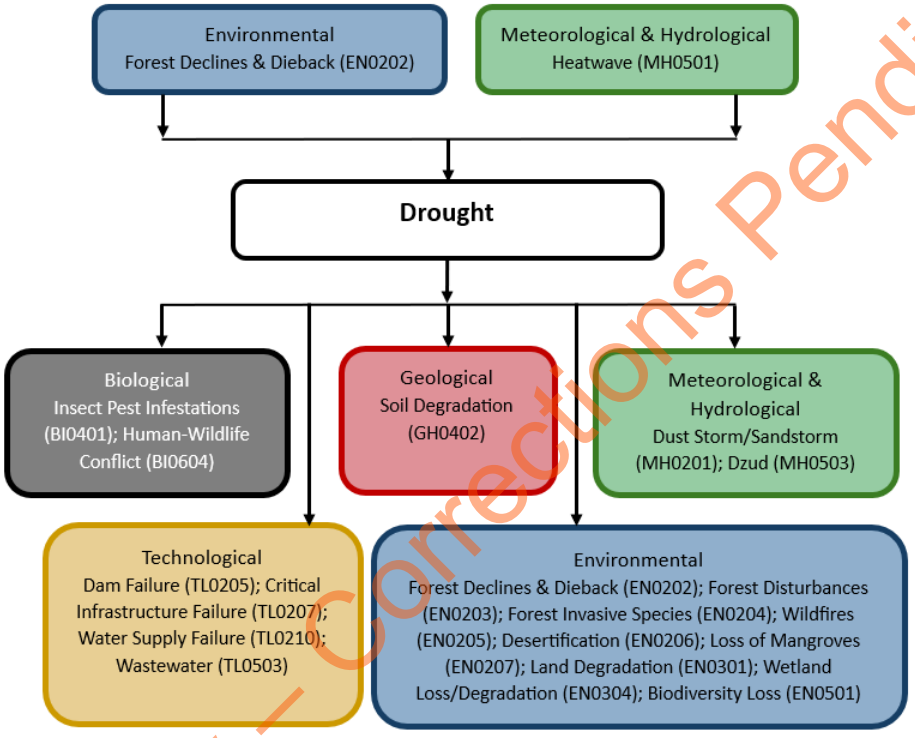
also affect air quality by making wildfires and dust storms more likely, increasing health risk in people already impacted by lung diseases, like asthma or chronic obstructive pulmonary disease (COPD), or with heart disease (WHO, 2025).

As the health cluster lead for global emergencies, the World Health Organization (WHO) works with partners to respond to drought-related disasters. This includes: ensuring appropriate food supplementation; health services, like immunisation, child and maternal health, and mental health; assembling mobile health teams and outreach; epidemic surveillance, early warning and response; and calling for emergency funding to support health action (WHO, 2025).

Multi-hazard Context: The figure below summarises common interactions between droughts and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section above and the table below offer an overview of monitoring droughts. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• National, subnational, and local disaster management agencies responsible for monitoring drought risks, issuing early warnings, and coordinating response strategies. • Meteorological services tracking precipitation patterns, temperature trends, and atmospheric conditions affecting drought. • Hydrological services monitoring groundwater levels, river flows, reservoir storage, and soil moisture conditions. • Drought Monitoring Centres are institutions that collect, analyse, and disseminate data on drought conditions. • Space and remote sensing agencies using satellites to monitor vegetation health, soil moisture, and water availability. • Agricultural and food security agencies assessing drought impacts on crop production, food supply, and livestock health. • Water resource management agencies evaluating freshwater availability, groundwater depletion, and sustainable water use policies. • Energy and utility companies monitoring hydropower production, energy demand fluctuations, and risks to water-dependent industries. • Land use and urban planners integrating drought risk assessments into zoning laws, water conservation strategies, and sustainable development plans. • Health authorities assessing public health risks related to water scarcity, food security, heat stress, and drought-related disease outbreaks.

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	• Researchers and academics, including climatologists, hydrologists, and agronomists, studying drought forecasting, climate change impacts, and mitigation strategies. • Environmental organisations and conservation groups advocating for sustainable land management, reforestation, and water conservation policies. • Community organisations and local governments engaged in drought awareness campaigns, water-saving initiatives, and local resilience-building efforts.
How is the Hazard Observed/Monitored/Forecast?	Drought is monitored using satellites, weather stations, and soil moisture sensors to track rainfall deficits, temperature trends, and water availability in rivers, lakes, and groundwater. Meteorologists analyse climate patterns, including El Niño and La Niña, to predict drought conditions. Advanced computer models simulate long-term weather and water trends, helping forecasters issue early warnings. Drought monitoring centres, such as the U.S. Drought Monitor and the European Drought Observatory, provide real-time assessments and forecasts to help governments, farmers, and communities prepare for and mitigate drought impacts.

Risk Management: There has been much work on drought management. The Integrated Drought Management Programme (IDMP), co-sponsored by the WMO and the Global Partnership Water (GWP), have developed a three-pillar approach to Integrated Drought Management. These pillars include: drought monitoring and early warning; drought vulnerability and impact assessment; and drought mitigation, preparedness and response. IDMP has over 35 partner organisations, including the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Convention to Combat Desertification (UNCCD). IDMP developed the National Drought Management Policy Guidelines, which include a 10-step process to assist countries in developing national drought plans and polices (WMO and GWP, 2014).

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Preliminary – Corrections Pending

Coordinating agency or organisation

World Meteorological Organization (WMO).

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MH0402 / METEOROLOGICAL AND HYDROLOGICAL / Precipitation-related

Rain

Definition

Rain is precipitation of drops of water that fall from a cloud (WMO, 2017). While rain is essential for sustaining life and ecosystems, extreme rainfall is a primary trigger for some of the most devastating secondary hazards–flooding, landslides, and soil erosion–which result in widespread loss of life, damage to infrastructure, disruption of livelihoods, and environmental degradation (Rijal et al., 2024; Myhre et al., 2019).

Reference

WMO, 2017. International Cloud Atlas: Rain. World Meteorological Organization (WMO). https://cloudatlas.wmo.int/en/rain.html Accessed 16 May 2025.

Myhre, G., Alterskjaer, K., Stjern, C. W., Hodnebrog, O., Marelle, L., Samset, B. H., Sillmann, J., Schaller, N., Fischer, E., Schulz, M. and Stohl, A., 2019: Frequency of extreme precipitation increased extensively with event rareness under global warming, *Scientific Reports,* 9(16063). https://www.nature.com/articles/s41598-019-52277-4 Accessed 16 May 2025.

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Preliminary – Corrections Pending

Annotations

Synonyms

Precipitation (specific to liquid water form), rainfall.

Additional scientific description

Rain develops as a result of small, suspended cloud droplets growing into larger drops of water, which then fall to earth because of their weight (MeteoSwiss, no date a). The number, density, and size distribution of raindrops vary considerably with the intensity and nature of the precipitation (WMO, 2017). Rain becomes a hazard when its intensity, duration, or frequency causes significant adverse impacts on human life, ecosystems, and infrastructure.

Metrics and numeric limits

According to the International Cloud Atlas (WMO, 2017), key indicators for rain can include:

(1) **Character** (intermittent or continuous);

(2) **Intensity** (slight, moderate, heavy): The measurement unit of rainfall intensity is linear depth per hour, usually in millimetres per hour (mm h-1). Rainfall intensity is normally measured or derived over one-minute time intervals due to the high variability of intensity from minute to minute (WMO, 2023).

Rainfall intensity can be either derived from the measurement of precipitation amount using a recording rain gauge or measured directly. The latter can be done, for example, by using a gauge and measuring the flow of the captured water, measuring the accretion of collected water as a function of time, or using some optical principles of measurement. A number of techniques for determining precipitation amount are based on these direct intensity measurements by integrating the measured intensity over a certain time interval (WMO, 2023).

While there is no agreed international definition regarding rainfall intensity, some use the following criteria: WMO's Severe Weather Information Centre (SWIC) defines heavy rain as rainfall greater than or equal to 50 mm in the past 24 hours (SWIC, 2024), while MeteoSwiss defines precipitation (including rain amongst others) of varying levels of intensity using the following terms and metrics:

Term	Total per 24 hours in mm	Explanation
Low	0.1 - 2	Some rain, light rain, scattered showers. A few drops, drizzle
Medium	2 - 10	Some precipitation, some showers (with occasional thunder)
High	10 - 30	Heavy precipitation, heavy rain (with occasional thunder)
Very high	30 - 50	Heavy precipitation, heavy rain (heavy thunderstorms)
Profuse	>50	Profuse precipitation/rainfall (severe thunderstorms)

Key relevant UN convention / multilateral treaty

Not identified.

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Rainfall events can result from various factors, and key drivers can include:

- *Extreme weather systems:* Heavy rain events can result from various atmospheric phenomena, such as extra-tropical cyclones, tropical cyclones, thunderstorms, squalls, or derechos, often accompanied by rainfall.
- *Climate change:* Human-induced climate change has been linked to an increase in the frequency and intensity of heavy rainfall events (Myhre et al., 2019). The warming climate contributes to higher atmospheric moisture levels, with scientists expecting every 1 °C air temperature rise to increase the atmosphere's moisture holding capacity by 6-7% (Rijal et al., 2024). This heightened moisture content can lead to more intense precipitation events as well as shifts in rainfall patterns and extremes, compounding existing vulnerabilities (Rijal et al., 2024).
- *Seasonal variations:* Seasonal changes, such as monsoons, significantly impact rainfall patterns. For example, the monsoons that cause the heaviest rainfall are summer monsoons near the Indian Ocean. Warm water in the ocean evaporates, rising into the air. This causes the wind to change direction, and moisture blows toward the land over South Asia (among other places). The warm, moist air then condenses and becomes rain. The result is a period of humidity and heavy rainfall that can last for months (NOAA, 2024; NASA, 2016).

Impacts: While rain is essential for sustaining life and ecosystems, it becomes a significant hazard when its intensity, duration, or frequency exceeds the absorptive and adaptive capacities of natural and built environments. Extreme rainfall is a primary trigger for some of the most devastating secondary hazards—flooding, landslides, and soil erosion—which result in widespread loss of life, damage to infrastructure, disruption of livelihoods, and environmental degradation (Rijal et al., 2024; Myhre et al., 2019).

Rainfall-induced disasters are among the most costly and deadly worldwide. In the U.S. alone, floods—driven predominantly by heavy rain—rank as the second leading cause of weather-related deaths and cause billions in annual damages (CDC, no date; US EPA, 2024). Moreover, intense rain events overwhelm stormwater systems, contaminate water supplies, and heighten the spread of disease, especially in urban and low-income settings. Some of the impacts associated with excess rainfall include:

- *Human and health impact:* Increased flooding as a result of heavy rainfall events can result in loss of life. In the U.S., for example, flooding due to the heavy rain associated with tropical storms has resulted in a high number of deaths, with floods ranked as the second leading cause of U.S. weather-related deaths, causing 98 fatalities annually. Beyond immediate impacts, heavy rainfall events can have lasting health impacts. Waterborne disease outbreaks often rise in the weeks following heavy rainfall, as reported in the U.S., and water intrusion into buildings can lead to mold growth, worsening indoor air quality. People living in damp environments face higher risks of respiratory issues, including asthma, pneumonia, and respiratory syncytial virus (RSV) (CDC, no date; US EPA, 2024).
- *Economic impact:* Flooding associated with heavy rainfall can damage buildings and infrastructure and disrupt key economic sectors, such as agriculture, transport, and energy sectors. Agriculture is significantly affected, as heavy rainfall can damage crops, erode nutrient-rich topsoil, and delay planting seasons, threatening farmers' livelihoods and food supply chains. Additionally, extreme precipitation can disrupt transportation, communication, and energy infrastructure, leading to blocked roads, damaged railways, and power outages, resulting in significant economic losses. In the U.S., for example, power disruptions associated with climate change-related events alone could cost over $8 billion annually by 2090 (US EPA, 2024).
- *Environmental impact*: Heavy rainfall events can also have negative environmental consequences, resulting from increased runoff. Rainfall-runoff processes are "the main hydrological link between terrestrial pollution sources and water bodies" (Chang et al., 2023). When excess water cannot be absorbed by the soil, it flows over the surface, collecting contaminants along the way. On agricultural lands, intense rainfall can lead to significant runoff, carrying fertilisers into nearby streams and lakes. Once these nutrients enter water bodies, they can fuel harmful algal blooms and deteriorate water quality, impacting sources used for drinking water and recreational activities (US EPA, 2024).

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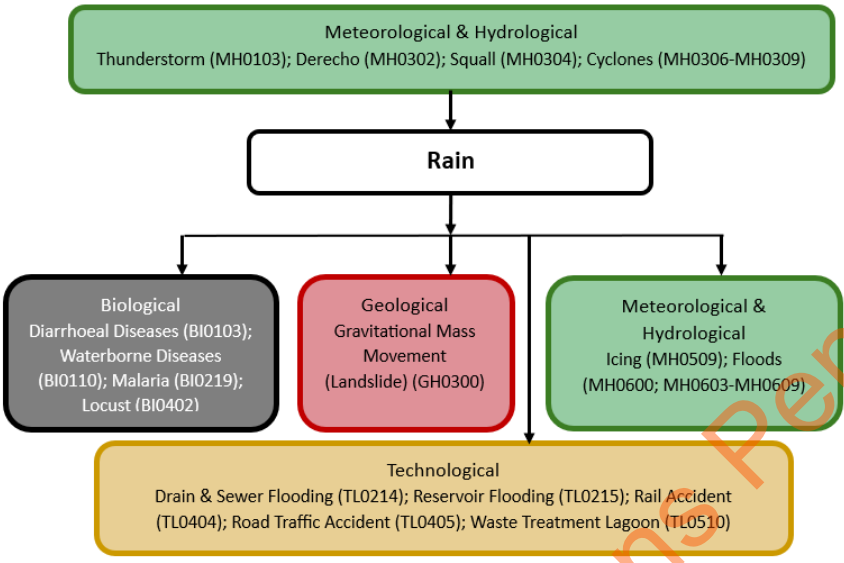
Multi-hazard Context: The figure below summarises common interactions between rain and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring rain. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• Meteorological service that tracks precipitation patterns, issue weather forecasts, and provide early warnings for heavy rainfall events. • Hydrological service assesses the impact of rainfall on river levels, watersheds, and potential flooding. • Geophysical agencies monitoring rainfall-induced hazards such as landslides, soil erosion, and ground instability. • National, subnational, and local disaster management agencies responsible for monitoring and responding to rainfall-induced hazards such as flooding and landslides. • Health authorities evaluating the effects of heavy rainfall on public health, including water contamination and vector-borne diseases. • Engineers designing stormwater drainage systems, flood control infrastructure, and erosion control measures. • Land use and urban planners integrating rainfall-related risk assessments into zoning laws and urban development strategies. • Researchers and academics, including social scientists, studying rainfall variability, climate change impacts, and community resilience to extreme precipitation. • Organisations and community representatives engaged in rainfall hazard preparedness, emergency response, and risk reduction initiatives.
How is the Hazard Observed/Monitored/Forecast?	Rain is monitored using weather radar, satellite images, and ground-based rain gauges that measure rainfall intensity and distribution in real-time. Meteorologists use these observations, combined with atmospheric models and historical data, to forecast future rainfall, predict intensity, and if necessary, issue advisories and early warnings. Advanced technologies, such as Doppler radar, help detect storm movement and potential hazards like flash floods. Experts improve rainfall predictions using these tools and specialised hazard risk models, help communities and decision-makers prepare for impacts related to rainfall.

Risk Management: Effective risk management strategies for heavy rainfall are essential to mitigate potential human impacts and damage to infrastructure, agriculture, and communities.

An example of a rain-related risk management strategy is the Integrated Heavy Rain Risk Management (RAINMAN) project, implemented by the European Union, to address the increased threats posed by heavy rainfall events. Launched in 2017 under the Interreg Central Europe program, RAINMAN aims to enhance the capacities of public authorities in Central Europe and to support local and regional administrations in mitigating heavy rain risks. The project focuses on developing innovative methods and tools to assess, map, and reduce these risks, thereby improving emergency response and reducing potential damage

Preliminary – Corrections Pending

(European Union, 2017).

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Myhre, G., Alterskjaer, K., Stjern, C. W., Hodnebrog, O., Marelle, L., Samset, B. H., Sillmann, J., Schaller, N., Fischer, E., Schulz, M. and Stohl, A., 2019. Frequency of extreme precipitation increased extensively with event rareness under global warming, Scientific Reports, 9(16063). [online] Available at: https://www.nature.com/articles/s41598-019-52277-4 Accessed 16 May 2025.

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National Oceanic and Atmospheric Administration (NOAA), no date. Glossary: Rain. NOAA's National Weather Service. [online] Available at: https://forecast.weather.gov/glossary.php?word=RAIN Accessed 16 May 2025.

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Rijal, M., Luo, P., Mishra, B. K., Zhou, M. and Wang, X., 2024. Global systematical and comprehensive overview of mountainous flood risk under climate change and human activities, Science of the Total Environment, 941(173672). [online] Available at: https://www.sciencedirect.com/science/article/abs/pii/S0048969724038191 Accessed 16 May 2025.

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Coordinating agency or organisation

World Meteorological Organization (WMO)

Preliminary – Corrections Pending

MH0403 / METEOROLOGICAL AND HYDROLOGICAL / Precipitation-related

Blizzard

Definition

A blizzard is a severe snowstorm characterised by poor visibility, usually occurring at high latitudes and in mountainous regions (WMO, 1992).

Reference

WMO, 1992. International Meteorological Vocabulary, No. 182. World Meteorological Organization (WMO). https://library.wmo.int/records/item/35809-international-meteorological-vocabulary?offset=2 Accessed 16 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

In Russia 'purga' or 'metel', Snow storm.

Additional scientific description

The term blizzard is generally used in North America and Great Britain. There are differing thresholds for defining and issuing warnings for blizzards.

Metrics and numeric limits

Thresholds for defining and issuing warnings for blizzards vary by country.

In the USA, a blizzard warning is issued for winter storms with sustained or frequent winds of 35 mph (56 km/hr) or higher, with considerable falling and/or blowing snow that frequently reduces visibility to 1/4 of a mile (0.4 km) or less. These conditions are expected to prevail for a minimum of 3 hours (Eye on the Sky, no date).

In the UK, a blizzard is defined as moderate or heavy falling snow (either continuous or in the form of frequent showers) with wind speeds of 30 mph (48 km/hr) or more and a reasonably extensive snow cover reducing visibility to 200 metres (0.13 miles) or less (UK Met Office, 2019).

In Canada, alerting parameters for issuing a blizzard warning include when winds of 40 km/hr or more are expected to cause widespread reductions in visibility to 400 metres (0.25 miles) or less, due to blowing snow, or blowing snow in combination with falling snow, for at least 4 hours. North of the tree line, the thresholds are the same as the national thresholds, except when conditions are expected to last for at least 6 hours (Government of Canada, no date).

Key relevant UN convention / multilateral treaty

Not applicable.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Blizzard occurs when snow and wind occur simultaneously.

Impacts: A blizzard is severe winter weather characterised by strong winds and heavy or blowing snow that causes low to zero visibility, with significant social and economic impacts:

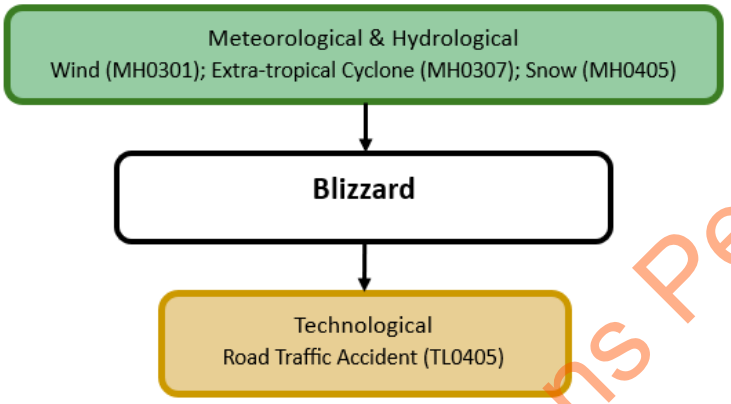
Health and safety impacts: Winter storms create a higher risk of car accidents, hypothermia, frostbite, carbon monoxide poisoning, and heart attacks from overexertion, etc. In whiteout conditions associated with blizzards, people have become lost even when going only short distances. To avoid these risks, the warnings and preventative instructions from local and national authorities should be followed.

Travel disruptions: Due to the reduced visibility and strong winds associated with blizzards, blizzards and snowstorms carry significant transportation challenges, causing poor road conditions, flight cancellations and train service suspensions.

Power outages: Heavy snow alongside the accumulation of ice can increase the weight on power lines, causing power line damage and, in turn, power outages.

Impacts on businesses: Blizzards and snowstorms may cause operational slowdowns, and in some cases, complete business closures, resulting in financial losses for affected businesses (Bureau of Meteorology, 2023).

Multi-Hazard Context: The figure below summarises common interactions between blizzards and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section above and the table below offer an overview of monitoring blizzards. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• National, subnational, and local disaster management agencies responsible for monitoring blizzard risks, issuing alerts, and coordinating emergency response efforts. • Meteorological services tracking snowfall rates, wind speeds, and atmospheric conditions contributing to blizzards. • Hydrological services monitoring snow accumulation, ice melt, and potential flooding risks after a blizzard. • Space and remote sensing agencies using satellite technology to track storm systems, cloud cover, and snowfall distribution. • Aviation safety authorities monitoring travel conditions, issuing advisories for flights and airports. • Transportation and infrastructure agencies assessing risks to roads, railways, and power grids from heavy snow, ice accumulation, and strong winds. • Energy and utility companies monitoring power demand and supply, preparing for potential outages caused by blizzards and ice storms. • Health authorities evaluating public health risks, including hypothermia, frostbite, respiratory issues, and emergency medical response needs due to extreme cold. • Researchers and academics, including climatologists and meteorologists, studying blizzard dynamics, forecasting improvements, and climate change impacts.
How is the Hazard Observed/Monitored/Forecast?	Blizzards are observed and monitored using satellites, weather radar, and ground-based sensors to track snowfall intensity, wind speeds, and temperature drops. Meteorologists analyse atmospheric pressure systems, jet stream patterns, and moisture levels to predict storm development. Advanced computer models simulate storm movement and severity, helping forecasters issue early warnings. These alerts assist communities, emergency responders, and transportation authorities in preparing for dangerous conditions, power outages, and travel disruptions.

Risk Management: No Information Available

References

Bureau of Meteorology, 2023: The Science of Snowstorms and Blizzards. https://bureauofmeteorology.org/blogs/weather-science/the-science-of-snowstorms-and-blizzards Accessed 16 May 2025.

Eye on the Sky (No date). Glossary of Weather Terms: Blizzard Warning. Accessible at: https://www.fairbanksmuseum.org/eye-on-the-sky/glossary. Accessed 16 May 2025.

Preliminary – Corrections Pending

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UK Met Office, 2019. Blizzards and Snow Drifts. www.metoffice.gov.uk/weather/learn-about/weather/types-of-weather/snow/blizzard Accessed 16 May 2025.

Coordinating agency or organisation

World Meteorological Organization (WMO)

Preliminary – Corrections Pending

MH0404 / METEOROLOGICAL AND HYDROLOGICAL / Precipitation-related

Hail

Definition

Hail is precipitation in the form of particles of ice (hailstones). These can be either transparent or partly or completely opaque. They are usually spheroidal, conical or irregular in form, and generally 5–50 mm in diameter. The particles may fall from a cloud either separately or agglomerated in irregular lumps (WMO, 2017).

Reference

WMO, 2017. International Cloud Atlas: Hail. World Meteorological Organization (WMO). https://cloudatlas.wmo.int/hail.html Accessed 16 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Hailstone, Hailstorm.

Additional scientific description

Falls of hail always occur as showers. They are generally observed during heavy thunderstorms (WMO, 2017).

Hailstones usually form around a nucleus, which may not be at their geometric centre. The nucleus may be anywhere between a few millimetres and a centimetre in diameter. The nucleus is spheroidal or conical and is composed of ice that is usually opaque, but sometimes transparent (WMO, 2017).

Hailstones can occur with a great variety of forms and dimensions, even within a single fall. An 'onion skin' formation, for example, consists of a nucleus surrounded by alternating layers of opaque and transparent ice. There are usually not more than five layers, except in very large hailstones, which have been found to have 20 or more layers. Some other hailstones do not have any layers and consist of transparent or opaque ice only. They typically have a density of between 0.85 g/cm^3 and 0.92 g/cm^3 but may have a lower density if they have large cavities filled with air. Some hailstones are partly composed of spongy ice, which is a mixture of ice, water, and air. In exceptional circumstances, large hailstones can stick together to form irregular lumps of giant hail (WMO, 2017).

Hailstones form when a nucleus collects cloud droplets or drops of rain. There is no general agreement on the nature of this nucleus; the tendency is, however, to admit that it is usually a particle of small hail that has formed around a snow pellet (WMO, 2017).

Metrics and numeric limits

Hail size is often estimated by comparing it to a known object, such as the scales available from NOAA (2019).

Key relevant UN convention / multilateral treaty

Not available.

Examples of hazard drivers, impacts, and risk management

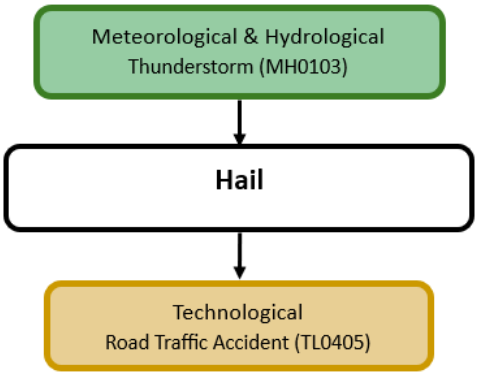
Hazard Drivers: Hail occurs during thunderstorms.

Impacts: Most hailstorms are made up of a mix of different sizes, and only the very largest hailstones pose serious risk to people caught in the open, as well as to agriculture, and vulnerable and exposed infrastructure.

The destructive effects of hailstorms upon plant and animal life, buildings and property, and aircraft in flight render them a

prime object of weather modification studies (AMS, 2012).

Multi-hazard Context: The figure below summarises common interactions between hail and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section above and the table below offer an overview of monitoring hail. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• National, subnational, and local disaster management agencies responsible for monitoring hailstorm risks, issuing warnings, and coordinating emergency response efforts. • Meteorological services tracking atmospheric conditions that lead to hail formation using satellites and radar to detect storm clouds and hail-producing weather systems. • Hydrological services monitoring precipitation patterns, stormwater runoff, and potential flooding caused by intense hailstorms. • Geophysical and atmospheric research institutions studying atmospheric instability, cloud microphysics, and weather conditions that influence hail formation. • Agricultural and food security agencies assessing the impact of hail damage on crops, livestock, and food supply chains. • Transportation and aviation authorities monitoring hail hazards for aircraft, highways, and railway systems, issuing advisories to minimize disruptions. • Insurance and risk assessment agencies evaluating hail damage trends for property, agriculture, and infrastructure to guide disaster preparedness. • Energy and utility companies monitoring risks to power lines, solar panels, and other energy infrastructure from hail-related damage. • Land use and urban planners integrating hail risk assessments into building codes, storm-resistant materials, and urban design strategies. • Health authorities assessing public safety risks from hail-related injuries, damaged shelters, and emergency medical response needs. • Researchers and academics, including meteorologists and climate scientists, studying hail formation, climate change impacts, and forecasting improvements. • Environmental organisations and conservation groups promoting climate resilience, severe weather preparedness, and risk mitigation strategies.
How is the Hazard Observed/Monitored/Forecast?	Hail is monitored using weather radar, satellites, and ground-based observations to detect thunderstorm clouds capable of producing hailstones. Meteorologists analyse temperature, wind patterns, and atmospheric instability to predict hail formation and intensity. Advanced computer models simulate thunderstorm development, helping forecasters issue early warnings. These alerts assist the public, farmers, drivers, airports, and emergency responders in preparing for possible hail impacts.

Risk Management: Examples of National Alerting Parameters for hail include those issued in China (China Meteorological Administration, 2012) and the United States, where a severe thunderstorm warning is issued when hail is forecast to be one inch or more in diameter (NOAA, 2020).

References

American Meteorological Society (AMS), 2012. Glossary of Meteorology: Hail. [online] Available at: http://glossary.ametsoc.org/wiki/Hail Accessed 16 May 2025.

Preliminary – Corrections Pending

China Meteorological Administration, 2012. Weather Warnings: Hail. [online] Available at: http://www.cma.gov.cn/en/WeatherWarnings/WarningSignals/201203/t20120320_166762.html Accessed 16 May 2025.

National Severe Storms Laboratory, National Oceanic and Atmospheric Administration (NOAA), 2019. Severe Weather 101: Hail. [online] Available at: https://www.nssl.noaa.gov/education/svrwx101/hail Accessed 16 May 2025.

National Weather Service, National Oceanic and Atmospheric Administration (NOAA), 2020. National Weather Service Instruction 10-511. [online] Available at: https://www.weather.gov/media/directives/010_pdfs/pd01005011curr.pdf Accessed 16 May 2025.

World Meteorological Organization (WMO), 2017. International Cloud Atlas: Hail. [online] Available at: https://cloudatlas.wmo.int/hail.html Accessed 16 May 2025.

Coordinating agency or organisation

World Meteorological Organization (WMO).

Preliminary – Corrections Pending

MH0405 / METEOROLOGICAL AND HYDROLOGICAL / Precipitation-related

Snow

Definition

Snow is the precipitation of ice crystals, isolated or agglomerated, falling from a cloud (WMO, 2017).

Reference

WMO, 2017. International Cloud Atlas Manual on the Observation of Clouds and Other Meteors: Snow. World Meteorological Organization (WMO). https://cloudatlas.wmo.int/snow.html Accessed 16 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Not identified.

Additional scientific description

The form, size and concentration of ice crystals differ considerably according to the temperature and supersaturation at which they develop. A fall of snow usually includes various types of snow crystals, and almost all types of crystals may be observed during a single fall of snow. Small droplets of frozen water are often attached to snow crystals. If present in great numbers, these can obscure the crystalline structure of the snow. At temperatures above about -5°C, the crystals generally clump to form snowflakes (WMO, 2017).

The National Oceanic and Atmospheric Administration (NOAA) National Severe Storms Laboratory reports the occurrence of various types of snow hazard (NOAA, 2019):

- *Snow flurries:* Light snow falling for short durations. No accumulation or light dusting is all that is expected.
- *Snow showers:* Snow falling at varying intensities for brief periods. Some accumulation is possible.
- *Snow squalls:* Brief, intense snow showers accompanied by strong, gusty winds. Accumulation may be significant. In North America, snow squalls are best known in the Great Lakes Region of Canada.
- *Blowing snow*: Wind-driven snow that reduces visibility and causes significant drifting. Blowing snow may be snow that is falling and/or loose snow on the ground picked up by the wind.
- *Blizzards*: Winds over 35 mph with snow and blowing snow, reducing visibility to 1/4 mile or less for at least 3 hours.
- *Wet snow*: Wet snow and ice rapidly accumulate on trees with leaves, causing the branches to snap under the load.

Metrics and numeric limits

Not available.

Key relevant UN convention / multilateral treaty

Not available.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: No Information Available

Impacts: Snow has impacts on different sectors:

Road transport: The main effect of snow and ice on roads is to reduce adhesion of the surface, resulting in loss of control and collisions. On hills, loss of traction may result in vehicles being unable to progress uphill. Blockage of the road leads to disruption according to the traffic density. Road operators attempt to maintain adhesion of the surface by application of salt and grit, both prior to and during ice and snow formation. However, heavy snow at temperatures well below 0°C requires very frequent treatment, which can be impossible to deliver to congested roads.

Rail transport: Trains are affected by loss of adhesion, and this is treated at vulnerable locations by application of sand. However, the main impacts of snow on rail transport are freezing of points and loss of electrical connection between electric trains and power supply from catenaries or especially from the third rail.

Airports and aircraft: The biggest delays at airports are usually caused by snow that impedes progress along taxiways and aprons. Compared with runways, these cover a vast area and are difficult to maintain in a clear state.

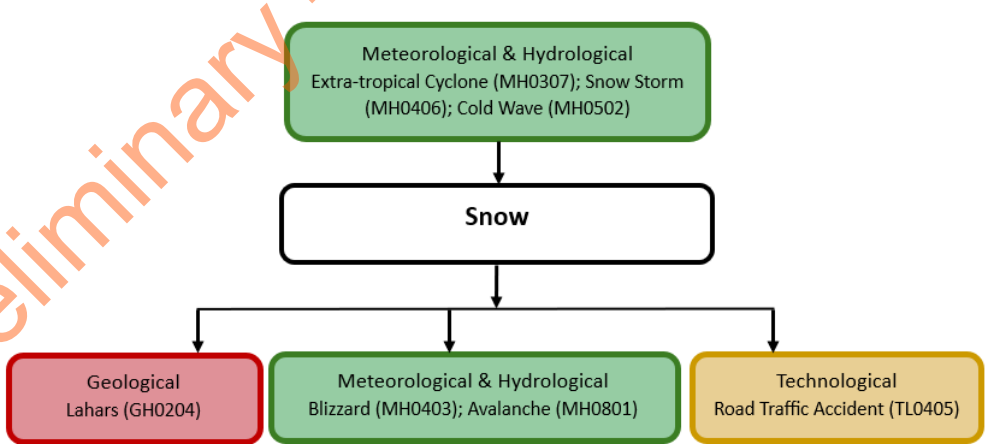
Energy supply and telecommunications: Wet snow and ice accumulate on transmission cables, trees, masts and pylons, especially when the temperature is close to freezing. The additional weight can lead to sagging of cables and collapse of trees and masts. The collapse of pylons is exceptional in the UK but has occurred in other countries in these conditions. Ice on electricity cables can affect transmission. The most frequent impacts are from falling trees that pull down local transmission cables with them.

Environmental impact: The main effects of snow on the environment are: the polluting potential from treatments used to prevent and remove ice from roads, vehicles and buildings; the polluting potential from accumulations of slurry and milk on farms due to road disruption; disposal of salt, grit and oil contaminated snow into rivers; and release of polluting materials as a result of freezing pipes etc. at industrial processes.

Health and health services: The health impacts of snow and icy surfaces that result from compacting snow on walkways and roads may be divided into two categories. Cold temperatures usually coexist with snow but have separate and more significant health effects.

- *Health:* The direct impacts are mainly broken bones and lacerations resulting from falls on ice-covered pavements and roads. The indirect impacts are injuries resulting from accidents incurred from the impact of snow and ice on travel, leading to road traffic accidents, etc. Loss of main water supplies due to frozen pipes which burst can also be a health risk, particularly for vulnerable individuals (such as those dependent on renal dialysis). Loss of power supplies during and after a snowstorm also impacts health, including obtaining health care supplies and continuing medical treatment for chronic illness in the community, such as dialysis. Injuries/infections sustained while clearing snow after a snowstorm.
- *Health services*: Impacts on health services include increases in hospital admissions for acute injury and trauma from slips and falls and other ice- and snow-related incidents, and acute presentation of chronic illnesses due to loss of essential services such as power, water and transport. This occurs in the background of increased demand for health services in winter, due to circulating infections such as influenza and the impact of cold temperatures on health.

Multi-hazard Context: The figure below summarises common interactions between snow and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Preliminary – Corrections Pending

Monitoring: The section above and the table below offer an overview of monitoring snow. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• National, subnational, and local disaster management agencies responsible for monitoring snowfall risks such as avalanches, issuing alerts, and coordinating emergency response efforts. • Meteorological services tracking snowfall accumulation, measuring snow cover and depth, storm intensity, and temperature conditions.

	• Hydrological services monitoring snowpack levels, snowmelt rates, and water availability in rivers, lakes, and reservoirs. • Transportation and infrastructure agencies assessing risks to roads, airports, railways, and power grids from heavy snowfall, ice buildup, and avalanches. • Energy and utility companies monitoring energy demand fluctuations, power outages, and risks to infrastructure caused by snow and ice. • Health authorities evaluating public health risks, including hypothermia, frostbite, respiratory illnesses, and emergency medical response needs due to extreme cold and snowstorms. • Researchers and academics, including climatologists and meteorologists, studying snow formation, climate change impacts, and forecasting improvements.
How is the Hazard Observed/Monitored/Forecast?	Snow is monitored using satellites, weather radar, and ground-based sensors and observations to track snowfall accumulation, intensity, and temperature changes. Meteorologists analyse atmospheric moisture, wind patterns, and pressure systems to predict when and where snow will fall. Advanced computer models simulate weather patterns related to snow development, helping forecasters issue early warnings. These alerts support transportation safety, infrastructure maintenance, and emergency response efforts, ensuring communities are prepared for heavy snowfall and potential disruptions.

Risk Management: The snowfall alert by Canada is an example of a national alerting parameter (Government of Canada, 2019).

References

Government of Canada, 2019. Criteria for Public Weather Alerts. [online] Available at: https://www.canada.ca/en/environment-climate-change/services/types-weather-forecasts-use/public/criteria-alerts.html#snowFall Accessed 31 January 2025.

National Oceanic and Atmospheric Administration (NOAA), 2019. Severe Weather 101. Types of Winter Weather. The National Severe Storms Laboratory, National Oceanic and Atmospheric Administration (NOAA). [online] Available at: https://www.nssl.noaa.gov/education/svrwx101/winter/types and Severe Weather 101: Winter Weather Forecasting. Accessed 16 May 2025.

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Coordinating agency or organisation

World Meteorological Organization (WMO).

Preliminary – Corrections Pending

MH0502 / METEOROLOGICAL AND HYDROLOGICAL / Temperature-related

Cold Wave

Definition

A cold wave is a period of marked and unusual cold weather characterised by a sharp and significant drop in air temperatures near the surface (maximum, minimum and daily average) over a large area and persisting below certain thresholds for at least two consecutive days during the cold season (WMO, 2020).

Reference

WMO, 2020. Guidelines on the Definition and Monitoring of Extreme Weather and Climate Events. World Meteorological Organization (WMO). https://library.wmo.int/viewer/58396/#page=1&viewer=picture&o=bookmark&n=0&q= Accessed 16 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Not available.

Additional scientific description

In the United States, the US National Weather Service defines a cold wave as a rapid fall in temperature within 24 hours to temperatures requiring substantially increased protection to agriculture, industry, commerce, and social activities. The criterion for a cold wave is thus twofold: the rate of temperature fall, and the minimum to which it falls. The latter depends on region and time of year (AMS, 2019).

In China, a cold wave is defined as disastrous weather in winter. Cold air coming down from high latitudes strengthens quickly under special weather conditions when entering middle and low latitude areas, which will bring a sharp temperature decrease, gales, snowfall and rainfall. When southward cold air reaches a certain standard, it will become a cold wave (China Meteorological Administration, 2012). A cold wave should not be confused with a 'cold spell', which instead refers to persistently below-average temperature conditions occurring during the warm season, which can also have severe impacts on society, in particular for human health and agriculture (WMO, 2020).

Metrics and numeric limits

The World Meteorological Organization guidelines on the definition and monitoring of extreme weather and climate events advise the following (WMO, 2020):

- *Index:* Daily values of Tmax, Tmin, and/or average temperature. Another index could be computed using temperature change in the 24 hours prior to the onset of the event.
- *Threshold:* Determined based on historical values of the index.
- *Temporal:* Station-level information on starting date, ending date, and duration of the event. Persistence of conditions for a cold wave are two days.
- *Spatial:* Calculate the area affected, by providing the percentage of stations where the threshold was surpassed; locate the coordinates of the impacted stations and the centre with the highest/lowest values of the indices; and optional, but recommended if resources are available, to use a geographical information system (GIS) to calculate the area affected by the event, the magnitude, and severity.

Key relevant UN convention / multilateral treaty

Not available.

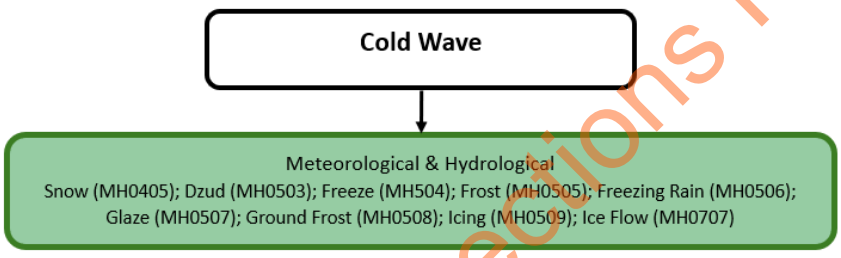
Examples of drivers, impacts, and risk management

Hazard Drivers: No Information Available

Impacts: Human health impacts from cold waves include mortality from ischaemic heart disease and cerebrovascular disease both of which increase in cold weather. An increase in respiratory disease is generally attributed to cross-infection from indoor crowding, and the adverse effects of cold on the immune system's resistance to respiratory infection, as well as to the fact that low temperatures assist survival of bacteria in droplets (Eurowinter Group, 1997).

Living in a cold house can affect health at any age, not just in old age, for a variety of reasons. Although the extra deaths in elderly people are caused mainly by cardiovascular and respiratory disease, far greater numbers have minor ailments that lead to a huge burden of disease, costs to the health system, and misery. Compared with those who live in a warmer house, respiratory problems are roughly doubled in children, arthritis and rheumatism increase, and mental health can be impaired at any age. Adolescents who live in a cold house have a five-fold increased risk of multiple mental health problems (Dear and McMichael, 2011).

Multi-hazard Context: The figure below summarises common interactions between cold waves and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section above and the table below offer an overview of monitoring cold waves. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• National, subnational, and local disaster management agencies responsible for monitoring cold wave risks, issuing warnings, and coordinating emergency response efforts. • Meteorological services tracking temperature drops, wind chill factors, and extreme cold conditions. • Hydrological agencies monitoring frozen water bodies, snowpack levels, and potential flooding risks from ice and snowmelt. • Space and remote sensing agencies using satellites to monitor temperature patterns, snow cover, and cold airmass movements. • Maritime and aviation safety authorities monitoring ice accumulation, low-visibility conditions, and issuing advisories for air and sea travel. • Transportation and infrastructure agencies assessing risks to roads, bridges, and railways from ice formation, frozen conditions, and extreme cold. • Energy and utility companies preparing for increased heating demand, power grid strain, and potential outages due to extreme cold. • Land use and urban planners integrating cold wave risk assessments into urban heating strategies, energy efficiency planning, and emergency response measures. • Health authorities evaluating public health risks, including hypothermia, frostbite, respiratory illnesses, and emergency medical response needs due to extreme cold exposure. • Researchers and academics, including climatologists and meteorologists, studying cold wave formation, climate change, and forecasting improvements.
How is the Hazard Observed/Monitored/Forecast?	Cold waves are monitored using satellites and weather stations with temperature sensors to track sudden drops in temperature, wind chill, and atmospheric pressure changes. Meteorologists analyse polar air movements, jet stream shifts, and moisture levels and advanced weather models to predict extreme cold events, enabling forecasters to issue early warnings. These alerts assist communities, energy providers, and emergency responders prepare for health risks, heating demands, and potential disruptions to infrastructure and transportation.

Risk Management: As an example, the Cold Weather Plan for England first launched in 2011 helps prevent the major avoidable effects on health during periods of cold weather in England (UK Government, 2020). National Alerting parameters for Cold Wave Warning are available in China (China Meteorological Administration, 2012).

Preliminary – Corrections Pending

References

AMS, 2019. Glossary of Meteorology: Cold wave. American Meteorology Society (AMS). http://glossary.ametsoc.org/wiki/Cold_wave Accessed 16 May 2025.

China Meteorological Administration, 2012. Weather Warnings: Cold Wave. www.cma.gov.cn/en/WeatherWarnings/Warning-Signals/201203/t20120320_166730.html Accessed 16 May 2025.

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Eurowinter Group, 1997. Cold exposure and winter mortality from ischaemic heart disease, cerebrovascular disease, respiratory disease, and all causes in warm and cold regions of Europe. Lancet, 349:1341-1346.

UK Government, 2020. Cold weather plan for England. https://www.gloshospitals.nhs.uk/media/documents/UKHSA_Cold_Weather_Plan_for_England.pdf. Accessed 16 May 2025.

WMO, 2020. Guidelines on the Definition and Monitoring of Extreme Weather and Climate Events. World Meteorological Organization (WMO). https://library.wmo.int/viewer/58396/#page=1&viewer=picture&o=bookmark&n=0&q= Accessed 16 May 2025.

Zhang, X., L. Alexander, G.C. Hegerl, P. Jones, A.K. Tank, T.C. Peterson, B. Trewin and F.W. Zwiers, 2011. Indices for monitoring changes in extremes based on daily temperature and precipitation data. WIREs Climate Change, 2:851-870.

Coordinating agency or organisation

World Meteorological Organization (WMO) and World Health Organization (WHO).

Preliminary – Corrections Pending

MH0503 / METEOROLOGICAL AND HYDROLOGICAL / Temperature-related

Dzud

Definition

A dzud (a Mongolian term that describes “severe winter conditions”, sometimes spelled zud) is a cold-season disaster in which anomalous climatic (i.e., heavy snow and severe cold) and/or land-surface (snow/ice cover and lack of pasture) conditions lead to reduced accessibility and/or availability of forage/pastures, and ultimately to high livestock mortality during winter-spring (Natsagdorj & Dulamsuren, 2001).

References

Natsagdorj, L. and J. Dulamsuren, 2001. Some aspects of assessment of the dzud phenomena. Pap Meteorol Hydrol 23:3-18 [in Mongolian].

Preliminary – Corrections Pending

Annotations

Synonyms

Winter storm, Blizzard, Cold surge.

Additional scientific description

There is a conventional classification of dzud types based on direct factors contributing to conditions that prevent animals from grazing for consecutive days, finally resulting in their starvation. These include (Fernandez-Gimenez et al., 2011):

- *White dzud:* Defined as conditions during which grasses that grow during the summer and decay during the subsequent cold season are covered by deep snow, preventing grazing. The snow depth during these conditions substantially exceeds plant height. This is the most common and disastrous dzud type.
- *Iron (or glass) dzud:* Happens when grasses are covered with impenetrable ice that is produced through melted and refrozen snow (most likely occurring during spring and autumn).
- *Black dzud:* Refers to freezing temperatures and lack of snow in winter (essential for livestock and human water) and limited forage/pasture due to preceding summer drought.
- *Storm and cold dzuds:* Both tend to result from strong winds, blizzards, and cold surge conditions. These weather patterns reduce the intake of pasture by livestock, which is determined by the availability of phytomass (i.e., not covered by snow and ice) and grazing time.

Hoof dzud is primarily associated with lack of pasture, often caused by overgrazing. This may occur when an excessive number of animals are concentrated in relatively good but limited pasturelands. A Dzud can occur as a cascading hazard to succeeding climatic hazards such as summer drought.

A combined (or multiple) dzud occurs when two or more of the above types of dzud occur together.

Note: human-induced vulnerability, including inadequate pasture management, lack of herder experience, poverty, and insufficient winter preparedness, can increase the risks of dzud impacts.

Metrics and numeric limits

Not available.

Key relevant UN convention / multilateral treaty

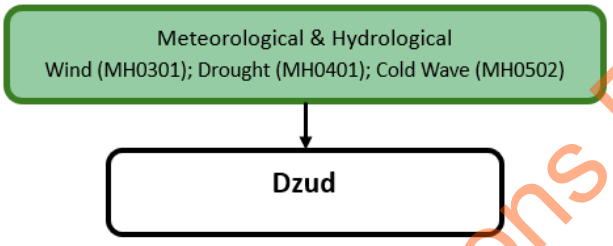
Not identified.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: A dzud is a compound hazard occurring in a cold, dry climate, and encompassing drought, heavy snowfall, extreme cold, and windstorms. Severe dzuds (high mortality) result from a combination of growing-season drought and severe weather (Natsagdorj and Dulamsuren, 2001; Nandintsetseg et al., 2017, 2018a,b).

Impacts: Dzud can last all year round and can cause mass livestock mortality and dramatic socioeconomic impacts, including unemployment, poverty, and mass migration from rural to urban areas, giving rise to heavy pressure on infrastructure and social and ecosystem services (Murray et al., 2012). Dzuds occurred in Mongolia in 1944-1945, 1954-1955, 1956-1957, 1967-1968, 1976-1977, 1986-1987, 1993-1994, and 1996-1997. The dzud of 1944-1945 was a record for the 20th century, with mortality of one-third of Mongolia's total livestock, with the 2009-2010 dzud causing similarly high animal mortality (Murray et al., 2012).

Multi-hazard Context: The figure below summarises common interactions between dzuds and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section above and the table below offer an overview of monitoring dzuds. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• National, subnational, and local disaster management agencies responsible for monitoring Dzud risks, issuing warnings, and coordinating emergency response efforts. • Meteorological services tracking temperature drops, snowfall levels, and extreme weather patterns leading to Dzud conditions. • Hydrological services monitoring snowpack accumulation, frozen water bodies, and potential drought conditions impacting livestock and agriculture. • Geophysical and atmospheric research institutions studying climate variability, Arctic air mass movements, and long-term temperature trends contributing to Dzud events. • Space and remote sensing agencies using satellite technology to monitor snow depth, vegetation health, and land surface temperatures. • Agricultural and livestock management agencies (e.g., Ministry of Food, Agriculture, and Light Industry of Mongolia) assessing the impact of extreme cold and food shortages on livestock survival. • Health authorities evaluating public health risks, including hypothermia, malnutrition, and disease outbreaks due to harsh winter conditions. • Energy and utility companies preparing for increased heating demand, fuel shortages, and infrastructure strain during extreme cold events. • Land use and rural development planners integrating Dzud risk assessments into sustainable pasture management, livestock policies, and climate adaptation strategies. • Researchers and academics, including climatologists, ecologists, and agronomists, studying Dzud formation, climate change impacts, and resilience strategies. • Environmental organisations and conservation groups advocating for rangeland management, disaster risk reduction, and climate adaptation in nomadic and rural communities. • International aid organisations (e.g., United Nations Development Programme (UNDP), World Food Programme (WFP), International Federation of Red Cross and Red Crescent Societies (IFRC)) providing support for early warning, humanitarian aid, and recovery efforts. • Local herder associations and community organisations engaged in early warning dissemination, livestock protection, and emergency preparedness for extreme winter conditions.

Preliminary – Corrections Pending

How is the Hazard Observed/Monitored/Forecast?	Dzud is monitored using satellites, weather stations, and ground sensors to track extreme cold, heavy snowfall, and vegetation conditions that impact livestock survival. Meteorologists analyse polar air movements, jet stream shifts, and moisture levels and advanced weather models to predict extreme cold events, enabling forecasters to issue early warnings. These warnings help herders, policymakers, and emergency responders prepare for livestock losses, food shortages, and energy demands in affected regions.

Risk Management: No Information Available

References

Fernandez-Gimenez, M., B. Batjav and B. Baival, 2011. Understanding Resilience in Mongolian Pastoral Social-ecological Systems. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/946711468061500091/mongolia-understanding-resilience-in-mongolian-pastoral-social-ecological-systems-adapting-to-disaster-before-during-and-after-2010-dzud Accessed 16 May 2025.

Murray, V., G. McBean, M. Bhatt, S. Borsch, T.S. Cheong, W.F. Erian, S. Llosa, F. Nadim, M. Nunez, R. Oyun, and A.G. Suarez, 2012. Case studies. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, pp. 487-542. www.ipcc.ch/site/assets/uploads/2018/03/SREX-Chap9_FINAL-1.pdf Accessed 16 May 2025.

Nandintsetseg, B., M. Shinoda and B. Erdenetsetseg, 2017. Contributions of multiple climate hazards and overgrazing to the 2009/2010 winter disaster in Mongolia. Natural Hazards, 92:109- 126. https://doi.org/10.1007/s11069-017-2954-8 Accessed 16 May 2025.

Nandintsetseg, B., M. Shinoda, Ch. Du and E. Munkhjargal, 2018a. Cold-season disasters on the Eurasian steppes: Climate-driven or man-made. Scientific Reports, 8:14769. https://doi.org/10.1038/s41598-018-33046-1 Accessed 16 May 2025.

Nandintsetseg, B., M. Shinoda and B. Erdenetsetseg, 2018b. Developing an early warning system of Dzud (cold-season disaster) in Mongolia. International Federation of Red Cross and Red Crescent Societies. https://www.researchgate.net/publication/340861520_Developing_an_Early_Warning_System_of_Dzud_cold-season_disaster_in_Mongolia Accessed 16 May 2025.

Coordinating agency or organisation

World Meteorological Organization (WMO).

Preliminary – Corrections Pending

MH0504 / METEOROLOGICAL AND HYDROLOGICAL / Temperature-related

Freeze

Definition

A freeze is an air temperature equal to or less than the freezing point of water (0°C) (adapted from WMO, 1992).

Reference

WMO, 1992. International Meteorological Vocabulary. World Meteorological Organization (WMO). https://library.wmo.int/records/item/35809-international-meteorological-vocabulary?offset=2 Accessed 16 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Frost, Freeze event, Killing frost.

Additional scientific description

Technically, the word 'frost' refers to the formation of ice crystals on surfaces, either by freezing of dew or a phase change from vapour to ice; however, the word is widely used by the public to describe a meteorological event when crops and other plants experience freezing injury (FAO, 2005).

Growers often use the terms 'frost' and 'freeze' interchangeably, with the vague definition being 'an air temperature less than or equal to 0°C'. A 'frost' is the occurrence of an air temperature of 0°C or lower, measured at a height of between 1.25 and 2.0 m above soil level, inside an appropriate weather shelter. Water within plants may or may not freeze during a frost event, depending on several avoidance factors (e.g., supercooling and concentration of ice-nucleating bacteria). A 'freeze' occurs when extracellular water within the plant freezes (i.e., changes from liquid to ice) (FAO, 2005).

Metrics and numeric limits

Not applicable.

Key relevant UN convention / multilateral treaty

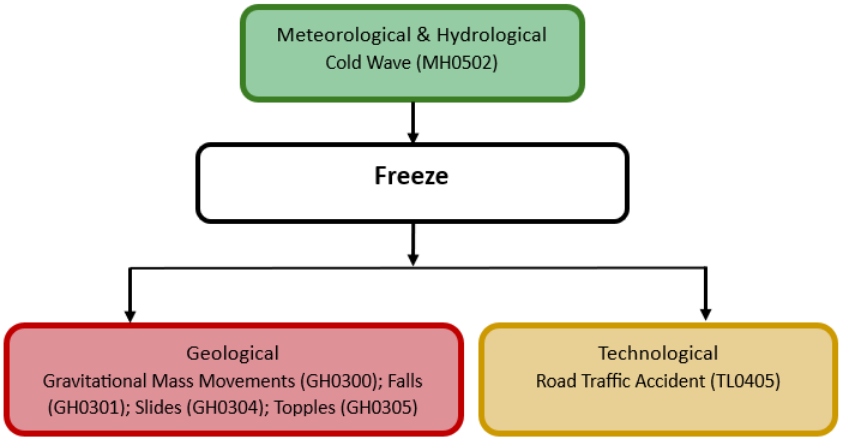
Not identified.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Freeze occurs during cold waves.

Impacts: The economic losses due to a widespread freeze event can be enormous. Direct crop losses can exceed a billion dollars. According to the United States National Climatic Data Center, five of the billion-dollar weather disasters over the past 30 years have been caused by agricultural freeze events (Brotak, 2014).

Multi-hazard Context: The figure below summarises common interactions between freeze and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section above and the table below offer an overview of monitoring freeze. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• National, subnational, and local disaster management agencies responsible for monitoring freeze risks, issuing alerts, and coordinating emergency response efforts. • Meteorological services tracking frost conditions using satellites and remote sensors to monitor land surface temperatures. • Hydrological services monitoring frozen water bodies, ice formation on rivers and lakes, and potential flooding risks from ice buildup. • Agricultural and food security agencies assessing the impact of freezes on crops, orchards, and food supply chains. • Energy and utility companies monitoring heating demand, power outages, and potential infrastructure failures due to extreme cold. • Transportation and infrastructure agencies assessing risks to roads, railways, and bridges from ice accumulation and freeze-thaw cycles. • Health authorities evaluating public health risks, including hypothermia, frostbite, and respiratory illnesses caused by freezing temperatures. • Researchers and academics, including meteorologists and climatologists, studying freeze formation and forecasting improvements.
How is the Hazard Observed/Monitored/Forecast?	Freezes are monitored using weather stations, satellites, and ground sensors to track temperature drops, frost formation, and wind chill. Meteorologists use weather models to forecast freezing temperatures to issue early warnings. These warnings assist farmers, energy providers, and emergency responders in protecting crops, infrastructure, and public health from extreme cold.

Risk Management: A number of different methods are available for preventing freeze damage to crops. It is important for growers to be aware of these so that they can evaluate which procedures are feasible and economical for combating freeze damage. The methods are described in terms of active and passive techniques. Active methods are those which are used when the danger of a freeze event is present and include such techniques as adding heat and covering crops. Passive methods are those used well in advance of the freeze event and include scheduling of planting and harvesting within the safe freeze-free period, and appropriate crop and field selection, among others.

References

Brotak, E., 2014. The big freeze: frost's costly impact on agriculture. Weatherwise, 67:30-35. https://www.tandfonline.com/doi/full/10.1080/00431672.2014.859937 Accessed 16 May 2025.

FAO, 2005. Frost Protection: fundamentals, practice and economics. Food and Agriculture Organization of the United Nations (FAO). www.fao.org/3/a-y7223e.pdf Accessed 16 May 2025.

Coordinating agency or organisation

World Meteorological Organization (WMO).

Preliminary – Corrections Pending

MH0505 / METEOROLOGICAL AND HYDROLOGICAL / Temperature-related

Frost (Hoar Frost)

Definition

A hoar frost is a deposit of ice produced by the deposition of water vapour from the surrounding air and is generally crystalline in appearance (WMO, 2017).

Reference

WMO, 2017. International Cloud Atlas: Hoar Frost. World Meteorological Organization (WMO). https://cloudatlas.wmo.int/hoar-frost.html Accessed 16 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Advection hoar frost, Radiation frost.

Additional scientific description

There are two types of hoar frost: hoar frost (proper) and advection hoar frost.

Hoar frost: A deposit of ice that generally assumes the form of scales, needles, features or fans and which forms on objects the surface of which is sufficiently cooled, generally by nocturnal radiation, to bring about the deposition of the water vapour contained in the ambient air. Hoar frost proper is ordinarily deposited on objects at or near the ground, mainly on their horizontal surfaces. Hoar frost is observed especially during the cold part of the year when the air is calm, and the sky is clear (WMO, 2017).

Advection hoar frost: A deposit of ice that generally assumes crystalline form and which forms on objects, the surface of which is sufficiently cold to bring about deposition of the water vapour contained in the air coming into contact with this surface, usually through a process of advection. Advection hoar frost is deposited mainly on vertical exposed surfaces. It is observed when relatively warm, damp air suddenly invades a region where the temperature of the exposed surfaces is below 0°C and below the frost point of the advected air (WMO, 2017).

Metrics and numeric limits

Not available.

Key relevant UN convention / multilateral treaty

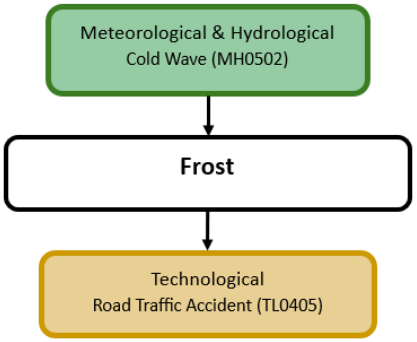
Not identified.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Hoar frost can form as a result of high humidity, light winds, and low temperatures, causing gaseous water vapour to transform directly into a solid state upon contact with solid surfaces - a process referred to as sublimation. Hoar frost typically "forms in the areas around the top of low stratus or fog, or where radiation is reflected away at fog margins at temperatures well below freezing" (MeteoSwiss, no date).

Impacts: The extent of frost damage is determined by how quickly the temperature takes to get to zero, the length of time temperatures stay below zero, and how far below zero the temperature falls. The effects of frost are particularly evident on vegetation, with frost impacting plant growth and seed production, with ripple effects for the agricultural sector (Wassan et al., 2021). According to the Australian Grains Research and Development Corporation (GRDC), the extent and type of frost damage depends on the growth stage of the plant at the time of the frost event, with, for example, crops such as wheat demonstrating high susceptibility to frost at flowering, while barley is increasingly susceptible during grain fill stage (GRDC, no date).

Multi-hazard Context: The figure below summarises common interactions between frost and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section above and the table below offer an overview of monitoring frost. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• National, subnational, and local disaster management agencies responsible for monitoring frost risks, issuing alerts, and coordinating emergency response efforts. • Meteorological services tracking frost conditions using satellites and remote sensors to monitor land surface temperatures and frost coverage. • Hydrological services monitoring frozen water bodies, ice formation on rivers and lakes, and potential flooding risks from ice buildup. • Agricultural and food security agencies assessing the impact of freezes on crops, orchards, and food supply chains. • Energy and utility companies monitoring heating demand, power outages, and potential infrastructure failures due to extreme cold. • Transportation and infrastructure agencies assessing risks to roads, railways, and bridges from ice accumulation and freeze-thaw cycles. • Health authorities evaluating public health risks, including hypothermia, frostbite, and respiratory illnesses caused by freezing temperatures. • Researchers and academics, including meteorologists and climatologists, studying Frost formation and forecasting improvements.
How is the Hazard Observed/Monitored/Forecast?	Frost is monitored using weather stations, satellites, and ground sensors to track temperature drops and frost formation. Meteorologists use weather models to forecast freezing temperatures and issue early warnings. These warnings assist farmers and energy providers in protecting crops, infrastructure, and public health from extreme cold.

Risk Management: No Information Available

References

Grains Research and Development Corporation (GRDC), no date. Frost management: Tips for identifying frost damage. https://grdc.com.au/resources-and-publications/resources/frost-management/tips-for-identifying-frost-damage. Accessed 16 May 2025.

Wassen, S., Xi, C., Binte-Imran, L., 2021. Effect of frost on plants, leaves, and forecast of frost events using convolutional neural networks. *International Journal of Distributed Sensor Networks*, 17(10). https://journals.sagepub.com/doi/full/10.1177/15501477211053777 Accessed 16 May 2025.

WMO, 2017. International Cloud Atlas: Hoar Frost. World Meteorological Organization (WMO). https://cloudatlas.wmo.int/hoar-frost.html Accessed 16 May 2025.

Coordinating agency or organisation

World Meteorological Organization (WMO).

Preliminary – Corrections Pending

MH0506 / METEOROLOGICAL AND HYDROLOGICAL / Temperature-related

Freezing Rain (Ice storm)

Definition

Freezing rain is rain where the temperature of the water droplets is below 0°C. Drops of supercooled rain may freeze on impact with the ground, in-flight aircraft or other objects (WMO, 2017).

Reference

WMO, 2017. International Cloud Atlas Manual on the Observation of Clouds and Other Meteors. WMO-No. 407. World Meteorological Organization (WMO). https://cloudatlas.wmo.int/en/supercooled-rain.html Accessed 16 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Freezing drizzle.

Additional scientific description

Freezing rain or freezing drizzle is precipitation that first falls in liquid form but then descends through a layer of cold air. If this layer is thick enough and the air temperature is below freezing, the precipitation freezes on contact with the ground (or an object that is below freezing temperature), forming a coating of ice on its surface. Driving and even walking can be dangerous in such conditions. Ice-coated utility lines or poles can be brought down due to the excess weight of the ice.

Freezing rain can sometimes land on surfaces exposed to the air (such as tree limbs) in air temperatures slightly above freezing in strong winds. Local evaporational cooling may result in freezing. Freezing rain frequently occurs, therefore, as a transient condition between the occurrence of rain and ice pellets (sleet). When encountered by an aircraft in flight, freezing rain can cause a dangerous accretion of clear icing (AMS, 2012).

When freezing rain and drizzle cause significant accumulation of ice on objects, it is referred to as an Ice storm (WMO, 1992).

Metrics and numeric limits

Ice storms with heavy accumulations of ice can bring down trees and topple utility poles and communication towers. Ice can disrupt communications and power for days while utility companies repair extensive damage. Even small accumulations of ice can be extremely dangerous to motorists and pedestrians. Bridges and overpasses are particularly dangerous because they freeze before other surfaces (AMS, 2012).

Key relevant UN convention / multilateral treaty

Not identified.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Freezing rain is a rare type of liquid precipitation that strikes a cold surface and freezes almost instantly. The weight of the ice can sometimes be enough to bring down trees and power lines, and the glaze of ice on the ground ('black ice') effectively turns roads and pathways into an ice rink. The freezing rain can also be extremely hazardous for aircraft (UK Met Office, no date).

Impacts: When freezing rain causes the heavy accumulation of ice, it can bring down trees and topple utility poles and communication towers. Ice can disrupt communications and power for days while utility companies repair extensive damage. Even small accumulations of ice can be extremely dangerous to motorists and pedestrians. Bridges and overpasses are particularly dangerous because they freeze before other surfaces (AMS, 2012).

Ice storms can have a very significant impact. The impact of the 1998 ice storm in Canada and the United States illustrates this.

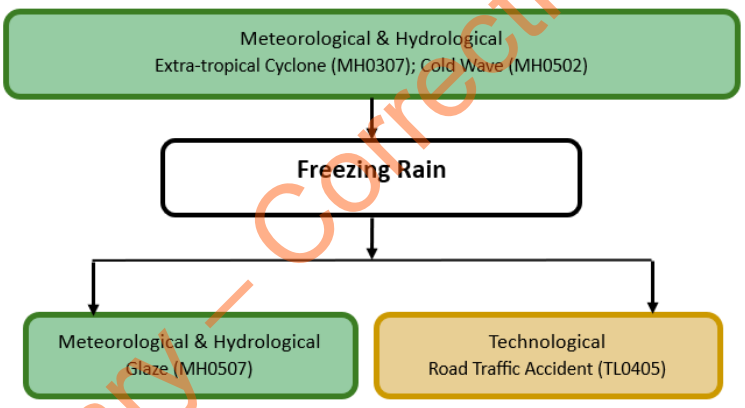
Late on 4 January 1998 freezing rain began to fall on eastern Ontario, southwestern Quebec, and southern New Brunswick and Nova Scotia, Canada. This continued for six days, ending on 10 January. These areas were pelted with 80 mm or more of freezing rain and the event doubled the amount of precipitation experienced in any prior ice storm. The result was a catastrophe that produced the largest estimated insured loss (CAD 1.44 billion) in the history of Canada (Lecomte et al., 1998).

The storm slashed across northern New York and parts of Vermont, New Hampshire and Maine in the United States, leaving a vast trail of damage and destruction (approximately USD 200 million in insured losses). Nevertheless, the damage in the United States paled in contrast to that sustained in Canada (Lecomte et al., 1998).

The combined Canadian and United States insured loss stands in excess of USD 1.2 billion or CAD 1.75 billion, as of 1 October 1998 (Lecomte et al., 1998). In Canada, 28 deaths were attributed to the storm; in the United States, 17 people lost their lives (Lecomte et al., 1998).

According to Emergency Preparedness Canada, electrical outages in the affected areas of Canada deprived 4.7 million people, or 16% of the Canadian population, of power. In the United States, 546,000 people were without electricity. Thus, in both countries, over 5 million people were without power (heat, light and in many instances, water) in the cold of mid-winter, which intensified the human suffering (Lecomte et al., 1998).

Multi-hazard Context: The figure below summarises common interactions between freezing rain and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section above and the table below offer an overview of monitoring freezing rain. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• National, subnational, and local disaster management agencies responsible for monitoring freezing rain and ice storm risks, issuing alerts, and coordinating emergency response efforts. • Meteorological services using weather observations, radar technology to detect and monitor freezing rain events and ice accumulation. • Transportation and infrastructure agencies assessing risks to roads, bridges, and railways from ice buildup, ensuring road salt and de-icing operations. • Energy and utility companies monitoring risks to power lines, transmission towers, and energy infrastructure from ice accumulation and potential outages. • Maritime and aviation safety authorities issuing advisories for ships, ports, and airports due to ice-related hazards affecting navigation and flight safety. • Health authorities evaluating public health risks, including hypothermia, injuries from icy conditions, and emergency medical response needs. • Researchers and academics studying freezing rain formation and mitigation strategies, including meteorologists, climatologists, and civil engineers.
How is the Hazard Observed/Monitored/Forecast?	Freezing rain and ice storms are monitored using weather radar, satellites, and ground-based sensors to track precipitation type, air temperature, and surface conditions. Meteorologists analyse temperature inversions, wind patterns, and humidity levels to predict when rain will freeze upon contact with the ground. Advanced computer models forecast freezing rain and ice

Preliminary – Corrections Pending

	accumulation, helping forecasters issue early warnings. These alerts assist transportation agencies, utility providers, and emergency responders in preparing for hazardous roads, power outages, tree and infrastructure damage caused by ice buildup.

Risk Management: In terms of national alerting thresholds, Canada issues a freezing rain warning when freezing rain is expected to pose a hazard to transportation or property, or when freezing rain is expected for at least two hours (in some provinces, four hours) (Environment Canada, no date). A winter weather watch is issued in the USA when any accretion of freezing rain or freezing drizzle on road surfaces is observed. A winter storm warning is issued when a half-inch (1.3 cm) or greater accretion of freezing rain is expected (NOAA, no date).

References

AMS, 2012. Glossary of Meteorology: Freezing rain. American Meteorological Society (AMS). http://glossary.ametsoc.org/wiki/Freezing_rain Accessed 16 May 2025.

Coburn J., Barthelemie, R., J., Pryor, S. C., 2024. Quantifying the compound hazard of freezing rain and wind gusts across CONUS. Environ. Res. Lett. 19 044016, 10.1088/1748-9326/ad30a4, https://iopscience.iop.org/article/10.1088/1748-9326/ad30a4 Accessed 16 May 2025.

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Environment Canada, no date. Alerting Parameters Environment Canada uses for Issuing a Freezing rain warning. www.canada.ca/en/environment-climate-change/services/types-weather-forecasts-use/public/criteria-alerts.html#freezingRain Accessed 16 May 2025.

Coordinating agency or organisation

World Meteorological Organization (WMO).

Preliminary – Corrections Pending

MH0507 / METEOROLOGICAL AND HYDROLOGICAL / Temperature-related

Glaze

Definition

Glaze is a smooth compact deposit of ice, generally transparent, formed by the freezing of super-cooled drizzle droplets or raindrops on objects with a surface temperature below or slightly above 0°C (WMO, 2017).

Reference

WMO, 2017. International Cloud Atlas: Glaze. World Meteorological Organization (WMO). https://cloudatlas.wmo.int/glaze.html Accessed 16 May 2025.

Preliminary — Corrections Pending

Annotations

Synonyms

Clear ice, glaze ice.

Additional scientific description

The deposit of ice formed by the freezing of fog or cloud droplets not supercooled at the time of impact with objects at temperatures well below 0°C, is known as glaze. Glaze on the ground must not be confused with ground ice, which, on a road surface, is known as 'black ice' (WMO, 2017).

Glaze covers all parts of surfaces exposed to precipitation. It is generally fairly homogeneous and morphologically resembles clear ice. At or near the ground, glaze forms when drizzle droplets or raindrops become supercooled as they fall through a layer of air at a sub-frost point temperature. In the free atmosphere, glaze is observed when aircraft are exposed to supercooled precipitation. Glaze forms by the slow freezing of supercooled liquid water and so penetrates the air gaps between the particles of ice before freezing (WMO, 2017).

Metrics and numeric limits

Not available.

Key relevant UN convention / multilateral treaty

Not available.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Glaze is denser, harder, and more transparent than either rime or hoarfrost. Its density may be as high as 0.8 or 0.9 g/cm3. Factors that favour glaze formation are large drop size, rapid accretion, slight supercooling, and slow dissipation of heat of fusion. The opposite effects favour rime formation. The accretion of glaze on terrestrial objects constitutes an ice storm, as a type of aircraft icing it is called clear ice. Glaze, as well as rime, may form on ice particles in the atmosphere. Ordinary hail is composed entirely (or nearly so) of glaze; the alternating clear and opaque layers of some hailstones represent glaze and rime, deposited under varying conditions around the growing hailstone (AMS, 2012).

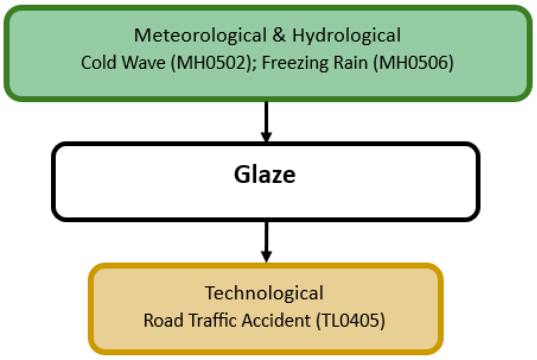
Impacts: Glaze is commonly associated with freezing rain events and can have significant consequences in terms of public safety and infrastructure.

Impacts on Transportation and Public Safety: Glaze poses severe risks to transportation systems. The ice-covered surfaces create extremely slippery conditions, leading to increased vehicle accidents and difficulties in pedestrian mobility. According to the Federal Highway Administration (FHWA), over 24% of weather-related vehicle crashes in the United States are due to "snow, slushy or icy pavement" (FHWA, 2024). Freezing rain events that produce glaze often result in road closures, airport shutdowns, and delays in public transit systems.

Damage to Infrastructure: One of the most significant impacts of glaze is on critical infrastructure, particularly power systems (Huang et al., 2022). The weight of the ice can cause power lines to snap or utility poles to collapse, resulting in widespread power outages.

For instance, the 1998 North American Ice Storm caused severe power disruptions, with over 4 million people affected and economic damages estimated at $4.4 billion (Gyakum and Roebber, 2001). The accumulation of ice on structures such as bridges, roofs, and communication towers can also lead to structural failures.

Multi-hazard Context: The figure below summarises common interactions between glaze and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section above and the table below offer an overview of monitoring glaze. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• National, subnational, and local disaster management agencies responsible for monitoring glaze risks, issuing alerts, and coordinating emergency response efforts. • Meteorological services using weather observations and radar technology to detect and monitor glaze accumulation. • Transportation and infrastructure agencies assessing risks to roads, bridges, and railways from glaze-induced ice accumulation and ensuring road salt and de-icing operations. • Energy and utility companies monitoring risks to power lines, transmission towers, and energy infrastructure from glaze-related ice accumulation and potential power outages. • Maritime and aviation safety authorities issuing advisories for ships, ports, and airports due to ice-related hazards affecting ships and flight operations. • Health authorities evaluating public health risks, including injuries from slippery surfaces, hypothermia, and emergency medical response needs during ice events. • Researchers and academics studying glaze formation and mitigation strategies, including meteorologists, climatologists, and civil engineers.
How is the Hazard Observed/Monitored/Forecast?	Glaze is monitored using weather radar and ground-based sensors to track precipitation type, air temperature, and surface conditions conducive to glaze formation. Meteorologists analyse temperature inversions, wind patterns, and humidity levels to predict when liquid precipitation will freeze upon contact with the ground. Advanced computer models forecast possible ice/glaze accumulation, helping forecasters issue early warnings. These warnings assist transportation agencies and the general public in preparing for hazardous walkways and roads, and other related impacts.

Risk Management: No Information Available

Preliminary – Corrections Pending

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FHWA, 2024: Road Weather Management. Snow and Ice. U.S. Department of Transportation Federal Highway Administration. https://ops.fhwa.dot.gov/weather/weather_events/snow_ice.htm Accessed 16 May 2025.

Gyakum, J. R. and Roebber, P. J., 2001: The 1998 Ice Storm – Analysis of a Planetary-Scale Event. https://journals.ametsoc.org/view/journals/mwre/129/12/1520-0493_2001_129_2983_tisaoa_2.0.co_2.pdf Accessed 16 May 2025.

Huang, W., Hu, B., Shahidehpour, M., San, Y., Sun, Q. and Yan, M., 2022. Preventative Scheduling for Reducing the Impact of Glaze Icing on Transmission Lines. *IEEE Transactions on Power Systems,* 37(2): 1297-1310. https://ieeexplore.ieee.org/document/9496094 Accessed 16 May 2025.

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Accessed 16 May 2025.

Coordinating agency or organisation

World Meteorological Organization (WMO).

Preliminary – Corrections Pending

EXTRATERRESTRIAL

Preliminary – Corrections Pending

ET0101 / EXTRATERRESTRIAL / Space Weather

Geomagnetic Disturbance

Definition

A geomagnetic disturbance refers to perturbations in Earth's magnetosphere caused by sudden and significant variations in the solar wind's speed, density, and magnetic properties. The intensity of a geomagnetic disturbance can be measured using different geomagnetic indexes. Although a geomagnetic disturbance is a global phenomenon, the intensities and characteristics vary at different geographic locations (NOAA, 2023).

Reference

NOAA Space Weather Prediction Center (2023) Geomagnetic Storms. Available at https://www.swpc.noaa.gov/phenomena/geomagnetic-storms Accessed 31 January 2025

Preliminary – Corrections Pending

Annotations

Synonyms

Magnetic storm, geomagnetic storm.

Additional scientific description

A geomagnetic disturbance is a substantial perturbation of Earth's magnetosphere, which arises due to the efficient injection of energy from the solar wind into the magnetosphere. These disruptions are triggered by fluctuations in the solar wind, leading to significant alterations in the currents, plasmas, and magnetic fields within Earth's magnetosphere. Geomagnetic disturbances typically occur during prolonged periods (lasting several to many hours) of high-speed solar wind, when the solar wind's magnetic field is oriented southward, opposing Earth's magnetic field dipole. This configuration notably facilitates the transfer of energy from the solar wind to Earth's magnetosphere, particularly on the dayside of the magnetosphere.

The intensity of a geomagnetic disturbance can be measured using different geomagnetic indexes. The K-index quantifies disturbances in the horizontal component of the Earth's magnetic field with an integer semilog in the range 0-9.0, with 1 being calm and 5 or more indicating a geomagnetic storm. It is derived from the maximum fluctuations of horizontal components observed on a magnetometer during a three-hour interval. The planetary 3-hour-range index Kp is the mean standardized K-index from 13 geomagnetic observatories at mid-latitudes between 44 and 60 degrees northern or southern geomagnetic latitudes. The label 'K' comes from the German word 'Kennziffer', meaning 'characteristic digit.'

The effects of geomagnetic disturbances range from mild, such as interference with aeromagnetic surveys, to extreme cases where electric power grids may experience blackouts or collapse. The most notable recorded solar superstorm, the Carrington Event, occurred in 1859. It was associated with a large solar flare, and the coronal mass ejections took only 17.6 hours to travel from the Sun to Earth. This event caused auroras to be observed where they are not typically seen, including equatorial latitudes. One consequence of the Carrington Event was the malfunctioning of telegraph systems worldwide, with operators receiving messages despite having disconnected their power supplies (Boteler, 2006; Clauer and Siscoe, 2006, Gonzalez-Esparza and Cuevas-Cardona, 2018).

In March 1989, the third strongest recorded geomagnetic disturbance struck Earth, resulting in severe consequences. Within a minute, induced currents in transmission lines triggered overload safety systems, leading to the shutdown of sections of the Quebec power network. This cascade effect caused a complete collapse of the network, plunging the region into darkness for nine hours. Restoration efforts were further complicated because the disturbance also affected backup equipment (CAA, 2016).

Different countries utilize various scales to assess and communicate the severity of geomagnetic disturbances. The common one is the K-level index. The K-index can be utilized locally (K-index) or planetary (Kp-index). Storms with minimal effects fall within the range of K=0-3, while mid-level effects occur for K=4-7. Strong disturbances with significant impacts are classified as K>7 (NRC, 2019). The K-index is used in Canada, Europe, Brazil, Mexico, and other regions worldwide to measure geomagnetic disturbances.

Metrics and numeric limits

Geomagnetic Disturbances are classified using a five-level scale introduced by the United States National Oceanic and Atmospheric Administration (NOAA, 2023) in 1999. The scale is currently under review and presented below. It is good to recognize that the Effect column also lists impacts typical during geomagnetic disturbances and related to other space weather hazards (ET0102, ET0103, ET0104). The Space Weather centres designated by the International Civil Aviation Organization (ICAO) are expected to provide airliners with advisories about anomalous conditions in HF communication when Kp exceeds the levels of 8 (for moderate activity, MOD) and 9 (for severe activity, SEV) (ICAO, 2019).

Scale	Description	Effect	Physical measure	Average Frequency (1 cycle = 11 years)
G5	**Extreme**	**Power systems:** Widespread voltage control problems and protective system problems can occur; some grid systems may experience complete collapse or blackouts. Transformers may experience damage. **Spacecraft operations:** May experience extensive surface charging, problems with orientation, uplink/downlink, and tracking satellites. **Other systems:** Pipeline currents can reach hundreds of amps, HF (high frequency) radio propagation may be impossible in many areas for one to two days, satellite navigation may be degraded for days, low-frequency radio navigation can be out for hours, and aurora has been seen at typically 40° geomagnetic lat.	Kp = 9	4 per cycle (4 days per cycle)
G4	**Severe**	**Power systems:** Possible widespread voltage control problems and some protective systems will mistakenly trip out key assets from the grid. **Spacecraft operations:** May experience surface charging and tracking problems, corrections may be needed for orientation problems. **Other systems:** Induced pipeline currents affect preventive measures, HF radio propagation sporadic, satellite navigation degraded for hours, low-frequency radio navigation disrupted, and aurora has been seen at typically 45° geomagnetic lat.	Kp = 8, including a 8.7	100 per cycle (60 days per cycle)
G3	**Strong**	**Power systems:** Voltage corrections may be required, false alarms triggered on some protection devices. **Spacecraft operations:** Surface charging may occur on satellite components, drag may increase on low-Earth-orbit satellites, and corrections may be needed for orientation problems. **Other systems:** Intermittent satellite navigation and low-frequency radio navigation problems may occur, HF radio may be intermittent, and aurora has been seen at typically 50° geomagnetic lat.	Kp = 7	200 per cycle (130 days per cycle)
G2	**Moderate**	**Power systems:** High-latitude power systems may experience voltage alarms, long-duration disturbances may cause transformer damage. **Spacecraft operations:** Corrective actions to orientation may be required by ground control; possible changes in drag affect orbit predictions. **Other systems:** HF radio propagation can fade at higher latitudes, and aurora has been seen at typically 55° geomagnetic lat..	Kp = 6	600 per cycle (360 days per cycle)
G1	**Minor**	**Power systems:** Weak power grid fluctuations can occur. **Spacecraft operations:** Minor impact on satellite operations possible. **Other systems:** Migratory animals are affected at this and higher levels; aurora is commonly visible at high.	Kp = 5	1700 per cycle (900 days per cycle)

Preliminary – Corrections Pending

Key relevant UN convention / multilateral treaty

Not available.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Solar activity: Geomagnetic disturbances are driven by CMEs and high-speed solar wind streams. Increased solar activity can lead to more frequent and increased chance of intense geomagnetic disturbances.

Impacts:

Electrical Grid Vulnerabilities: Geomagnetic disturbances can induce currents in long electrical conductors, particularly in power grids. This can lead to voltage instabilities and transformer damage, potentially resulting in widespread power outages, as was experienced during the Quebec event in 1989. During severe geomagnetic disturbances, the changing magnetic fields induce electric currents in power transmission lines. The geomagnetically-induced currents (GIC) can overload transformers and other equipment, leading to disruptions and damage to power grids. In extreme geomagnetic disturbances, the impacts on power grids can go beyond GIC-induced damage. The rapid fluctuations in the Earth's magnetic field can affect the operation and stability of

power systems, potentially leading to blackouts or grid instability.

Communication Disruptions: The disturbances can interfere with radio frequencies used for communication, especially affecting high-frequency radio communications and GPS systems. This can disrupt aviation, marine, and terrestrial communications, including emergency services that rely on these systems.

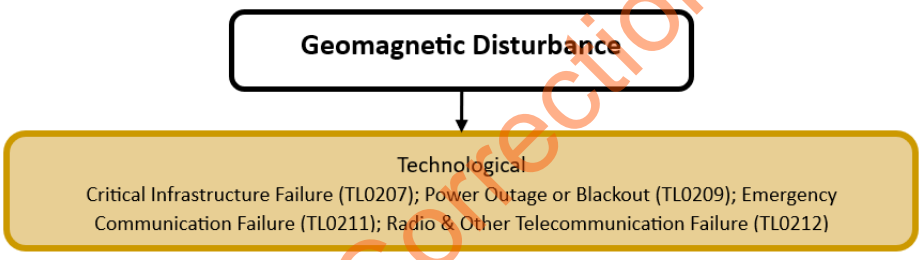
Satellite Operations: Satellites are particularly vulnerable to geomagnetic storms due to their exposure to intensified radiation and charged particles. This can lead to temporary or permanent damage to satellite electronics, loss of satellite control, and degradation of the accuracy of satellite-based navigation and communication systems.

Pipeline Corrosion: Geomagnetically induced currents (GICs) can also accelerate corrosion in pipelines carrying oil and gas. This not only risks the structural integrity of the pipelines but also increases the risk of leaks, which can have environmental and economic impacts.

Aviation Risks: Increased radiation levels during geomagnetic storms can pose risks to flight crews and passengers at high altitudes, particularly on polar routes. Airlines may need to reroute flights, leading to increased flight times and fuel consumption.

Economic and Social Impact: The combined effects on power grids, communication systems, satellite operations, and pipelines can have cascading impacts on various sectors including healthcare, finance, and emergency services, potentially leading to significant economic losses and social disruption.

Multi-hazard Context: The figure below summarises common interactions between geomagnetic disturbance and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: Space weather services members of the International Space Environment Services (ISES) offer warning systems to specific users in their countries. The Space Weather centres designated by the International Civil Aviation Organization (ICAO) provide airliners with advisories about geomagnetic storms.

Risk Management: Space weather monitoring: A range of organizations monitor solar activity, solar wind parameters, and the geomagnetic conditions around the Earth. The geomagnetic storm evolution can be monitored from space and ground-based vantage points, using planetary and regional geomagnetic indices.

Geomagnetic storm predictions: The predictions of a geomagnetic storm are provided to alert and prepare for future conditions. Space weather services can provide products for operators, e.g., power systems and pipelines, and radiofrequency management.

References

Boteler, D.H., 2006. The super storms of August/September 1859 and their effects on the telegraph system. Advances in Space Research, 38:159-172.

CAA, 2016. Impacts of Space Weather on Aviation. Civil Aviation Authority (CAA). https://www.caa.co.uk/publication/download/15787 Accessed 31 January 2025.

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Clauer, C.R. and G.E. Siscoe, 2006. The Great Historical Geomagnetic Storm of 1859: A Modern Look. Advances in Space Research, 38:115-388.

ESA, no date. Geomagnetic Conditions Expert Service Centre (G-ESC). ESA Space Weather Service Network. https://swe.ssa.esa.int/geomagnetic-conditions Accessed 31 January 2025.

González-Esparza, J.A. and MC Cuevas-Cardona, 2018. Observations of Low-Latitude Red Aurora in Mexico During the 1859 Carrington Geomagnetic Storm. Space weather, 16. https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2017SW001789 Accessed 31 January 2025.

Preliminary – Corrections Pending

International Civil Aviation Organization. Manual on SpaceWeather Information in Support of International Air Navigation (Doc 10100); Technical report; ICAO: Montréal, Canada, 2019.

Riley, P. and J. J. Love, 2017. Extreme geomagnetic storms: probabilistic forecast and their uncertainties. Space Weather, 1(14): 16-27.

NOAA, 2019. NOAA Space Weather Scales. Space Weather Prediction Center, National Oceanic and Atmospheric Administration (NOAA). https://www.swpc.noaa.gov/noaa-scales-explanation Accessed 31 January 2025.

The classical and the most used geomagnetic storm classifications (by Dst and Bz) are given in:

Gonzalez, W.D., Joselyn, J.A., Kamide, D., Kroehl, H.W., Rostoker, G., Tsurutani, B.T., Vasyliunas, V.M.: What is a geomagnetic storm? J. Geophys. Res., 99, 6, 5771-5792 (1994).

Loewe, C.A., Prölss, G.W.: Classification and mean behavior of magnetic storms, Journal of Geophysical Research, 102, 14209-14213 (1997). https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/96JA04020 Accessed 31 January 2025.

Coordinating agency or organisation

World Meteorological Organization (WMO) in collaboration with other space weather organisations.

Preliminary – Corrections Pending

ET0102 / EXTRATERRESTRIAL / Space Weather

Ionospheric Disturbances

Definition

Ionospheric disturbances refer to the state of the ionosphere characterized by irregular variations of ionospheric parameters without a systematic pattern. These disturbances can be of different spatiotemporal scales and have distinct characteristics at different geographic locations. Different ionospheric disturbances pose different risks to various applications (WMO, 1992).

Reference

WMO, 1992. International Meteorological Vocabulary. World Meteorological Organization (WMO), Report No. 182. https://library.wmo.int/records/item/35809-international-meteorological-vocabulary?offset=2 Accessed 31 January 2025.

Annotations

Synonyms

Ionospheric storms, space weather disruptions, TEC anomalies, radio wave scintillation.

Additional scientific description

Ionospheric disturbances can originate from space weather events, including solar flares, solar particle events, geomagnetic storms, and ionospheric pre-reversal enhancement, especially at night local time, due to fast vertical ionospheric drift. These disturbances can severely disrupt radio-wave propagation, particularly at high latitudes (AMS, 2012). The ionosphere, a part of Earth's upper atmosphere, plays a pivotal role in reflecting and modifying radio waves for communication, navigation, and radar tracking of space objects. The air in the ionosphere is ionized. Large amounts of free electrons are present within the range of 103 - 106 per 1 cm3. The electron concentration depends on the ionospheric region and geophysical conditions. The Sun, emitting X-ray and ultraviolet radiation, is the primary ionization source. Free electrons enable radio wave reflection in the ionosphere, facilitating long-distance radio propagation through reflections from ionospheric regions and the Earth's surface.

The electron concentration in the ionosphere undergoes variations of different spatiotemporal scale, most of which depend on variations in solar UV and X-ray fluxes. This flux variation leads to corresponding changes in ionospheric density. Particle precipitation, particularly at high latitudes, significantly influences ionospheric behaviour. The ionosphere comprises D, E, F1, and F2 regions, with local maxima of electron density. The F region, housing the main maximum of electron density in the ionosphere, is particularly notable. Solar irradiance influences ionization, resulting in the pole facing away from the Sun compared to the day-side and the pole facing the Sun (NOAA, 2019b). Solar proton bursts and particle precipitation cause effects in the ionosphere mostly at high latitudes. The impacts of solar proton bursts and auroral precipitation can be observed, particularly at high latitudes and in the polar caps.

An ionospheric storm, whether positive or negative, is a specific type of ionospheric disturbance characterized by an increase or decrease in the electron concentration within the F2 region during and/or after a geomagnetic storm compared to its quiet values. Ionospheric disturbances are a combination of ionospheric and atmospheric phenomena that are influenced by various factors, including the coordinates of the observation point, local time, season, and other conditions.

Metrics and numeric limits

Due to their high regional specifics, there is no global index/scale for ionospheric disturbances. The impact estimation for each region is based on the regional diagnostics.

The Space Weather Centres designated by the International Civil Aviation Organization (ICAO) are expected to provide airlines with advisories about anomalous conditions in HF communication and in GNSS performance based on the following parameters and thresholds (ICAO, 2019):

Preliminary — Corrections Pending

Impact	Parameter	MOD	SEV
GNSS Ampl. Scint.	S_4	0.5	0.8
GNSS Phase Scint.	σ_ϕ	0.4 rad	0.7 rad
Ionospheric delay in GNSS signal	Total Electron Content	125 TECU (1 TECU= 10^{16} el/m^2)	175 TECU
Polar Cap Absorption of HF waves	Cosmic Noise Absorption by ionospheric D-layer	2 dB	5 dB
Post Storm Depression of HF reflectivity	Decrease in the Maximum Usable Frequency	30%	50%

Key relevant UN convention / multilateral treaty

None identified.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Drivers, among others, include solar activity: Many ionospheric disturbances are driven by solar activity, including solar flares, solar particle events, and coronal mass ejections. Increased solar activity can lead to more frequent and intense ionospheric storms.

Fast solar wind streams causing stream interaction regions in the solar wind can also drive ionospheric disturbances. Irregular drivers include intensive tropospheric convection, seismic activity, artificial explosion, and solar eclipses.

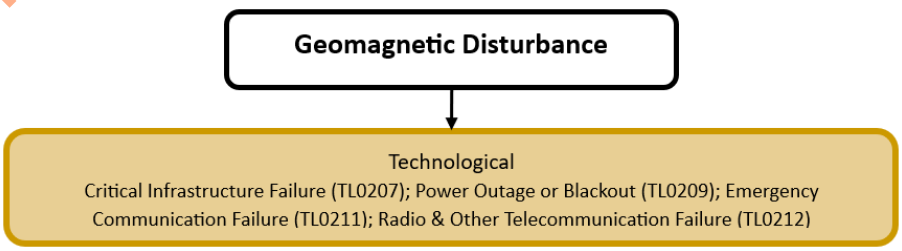
Impacts: Disruption of radio communication: Ionospheric disturbances can affect sky-wave radio wave propagation, leading to quality degradation or failure of communication links in the affected regions. More specifically, it can impact HF (high-frequency) radio communications, crucial for aviation, maritime operations, and emergency services This can impact air traffic control communications, aircraft-to-aircraft communications, and other radio-based systems used in aviation.

Navigation errors: ionospheric disturbances can also introduce errors in GNSS signals, in particular, it degrades the accuracy and reliability of Global Navigation Satellite Systems (GNSS) causing errors in positioning, navigation, and timing systems.

Satellite drag: increases atmospheric drag on satellites in low Earth orbit, altering orbital dynamics and potentially shortening satellite lifespans. Ionospheric disturbances can produce large short-term increases in upper atmosphere temperature and density, increasing drag on satellites and changing their orbits. Challenges to radio astronomical observations and other space research activities, as precise signal transmission and reception through the ionosphere are affected.

GNSS navigation disruptions affect industries relying on precise positioning, such as construction, agriculture, and logistics. Emergency response and disaster management suffer delays due to compromised communication channels, impacting coordination during natural disasters or crises.

Multi-hazard Context: The figure below summarises common interactions between ionospheric disturbances and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: Space weather services members of the International Space Environment Services (ISES) provide warning systems for specific users in their countries. The Space Weather centres designated by the International Civil Aviation Organization (ICAO) issue advisories about ionospheric disturbances to airlines.

Risk Management:

Space weather monitoring: A range of organizations monitor conditions and provide alerts and forecasts related to ionospheric storms. This allows stakeholders to be aware of potential impacts and take necessary precautions.

Flight diversion and postponement: In cases where ionospheric disturbances pose a significant risk to aviation operations, flights may be diverted to alternate routes or postponed until the storm subsides. This helps mitigate the potential impacts of disrupted

Preliminary – Corrections Pending

radio communication and navigation errors. Airlines and aviation organizations implement mitigation strategies to minimize the impacts of ionospheric disturbances. This may include implementing alternative communication systems, using backup navigation methods, and ensuring pilots and air traffic controllers are trained to handle space weather-related disruptions.

Satellites require shielding and surge protection to safeguard sensitive electronics. Establish redundant ground stations in geographically diverse locations to maintain satellite communication even if one station is affected by ionospheric disturbances. Develop redundancy in communication links by utilizing diverse frequency bands, communication paths, and transmission modes. This ensures that alternative channels can be quickly activated if primary communication links are disrupted.

Atmospheric density: Various organizations provide services for atmospheric conditions influenced by space weather.

References

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Coordinating agency or organisation

World Meteorological Organization (WMO) in collaboration with other space weather organisations.

Preliminary – Corrections Pending

ET0103 / EXTRATERRESTRIAL / Space Weather

Solar Flares

Definition

A solar flare is a sudden and large explosion on the Sun characterized by the rapid release of energy, resulting in the emission of electromagnetic radiation across all wavelengths and a rapid increase in brightness on a portion of the Sun's surface. The sudden outburst of electromagnetic energy travels at the speed of light therefore any effect upon the sunlit side of Earth's exposed outer atmosphere occurs at the same time the event is observed (NOAA Space Weather Prediction Center, 2023).

Reference

NOAA Space Weather Prediction Center (2023) SOLAR FLARES (RADIO BLACKOUTS). https://www.swpc.noaa.gov/phenomena/solar-flares-radio-blackouts Accessed 31 January 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Radio Blackouts, D region absorption; Solar X-ray Event, Ionospheric blackout; Radio fadeout:

Additional scientific description

Solar flares predominantly occur in active regions on the Sun, which are characterized by the presence of intense magnetic fields, often associated with sunspot groups. As these magnetic fields undergo changes and evolve, they can reach a state of instability, resulting in the release of energy in various forms. One of the primary manifestations of this energy release is observed as solar flares, which involve the emission of electromagnetic radiation.

Flares are more likely to occur during periods of high solar activity and are often accompanied by coronal mass ejections (CME).

Flares are classified based on their intensity, primarily determined by the X-ray brightness, and measured in the 1-8 Å band (0.1-0.8 nm). There are five categories of flares, ranging from the weakest to the strongest: A, B, C, M, and X (Hanslmeier, 2007; Schrijver, 2009). Information regarding the intensity of flares is obtained from X-ray and Extreme UV sensors installed on GOES satellites (Thiemann et al., 2019; Machol et al., 2020).

Under favourable observation conditions, when the corresponding active region on the Sun is facing Earth, an intense flare, typically of X-class and occasionally M-class, can lead to significant disturbances in the ionosphere on the sunlit side of Earth. These disturbances can cause signal distortions and radio fadeouts due to increased absorption of radio waves in the lower ionosphere, specifically the D region and lower E region.

Under regular conditions, high-frequency (HF) radio waves support long-distance communication by refracting through the upper layers of the ionosphere. However, during a powerful solar flare, the ionization increases in the lower ionosphere, particularly in its D and lower E regions. This phenomenon can lead to the degradation or complete absorption of HF radio signals, resulting in a radio fadeout that predominantly affects the 3 to 30 MHz frequency band.

Radio bursts are associated with solar flares. The delay in registration of its different radio frequencies at Earth's orbit is due to the outward movement of the source. Large bursts last 10 to 20 minutes on average. Longer radio noise storms of persistent and variable high radiation levels originate in sunspot groups, areas of large, intense magnetic fields. A Solar Radio Burst (SRB) could influence the Global Navigation Satellite System (GNSS) signals through direct radio wave interferences.

Metrics and numeric limits

Solar flare intensities cover a broad range and are classified in terms of peak emission in the 0.1 – 0.8 nm spectral band (soft x-rays) of the NOAA/GOES XRS. Solar flares are classified using a five-level scale introduced by the United States National

Oceanic and Atmospheric Administration (NOAA) in 1999. The scale is currently under review and presented below. The X-ray flux levels start with the 'A' level (A ≥ 10^{-8} W/m²). The next level, ten times higher, is the 'B' level (≥ 10^{-7} W/m²), followed by 'C' flares (10^{-6} W/m²), 'M' flares (10^{-5} W/m²), and finally 'X' flares (≥10^{-4} W/m²) (NOAA, 2023)."

Scale	Description	Effect	Physical measure (W/m²)	Average Frequency (1 cycle = 11 years)
R5	**Extreme**	**HF Radio:** Complete HF (high frequency) radio blackout on the entire sunlit side of the Earth, lasting for a number of hours. This results in no HF radio contact with mariners and en-route aviators in this sector. **Navigation:** Low-frequency navigation signals used by maritime and general aviation systems experience outages on the sunlit side of the Earth for many hours, causing loss in positioning. Increased satellite navigation errors in positioning for several hours on the sunlit side of Earth, which may spread into the night side.	X20 (2 x 10^{-3})	Less than 1 per cycle
R4	**Severe**	**HF Radio:** HF radio communication blackout on most of the sunlit side of Earth for one to two hours. HF radio contact lost during this time. **Navigation:** Outages of low-frequency navigation signals cause increased error in positioning for one to two hours. Minor disruptions of satellite navigation possible on the sunlit side of Earth.	X10 (10^{-3})	8 per cycle (8 days per cycle)
R3	**Strong**	**HF Radio:** Wide area blackout of HF radio communication, loss of radio contact for about an hour on sunlit side of Earth. **Navigation:** Low-frequency navigation signals degraded for about an hour.	X1 (10^{-4})	175 per cycle (140 days per cycle)
R2	**Moderate**	**HF Radio:** Limited blackout of HF radio communication on sunlit side, loss of radio contact for tens of minutes. **Navigation:** Degradation of low-frequency navigation signals for tens of minutes.	M5 (5 x 10^{-5})	350 per cycle (300 days per cycle)
R1	**Minor**	**HF Radio:** Weak or minor degradation of HF radio communication on sunlit side, occasional loss of radio contact. **Navigation:** Low-frequency navigation signals degraded for brief intervals.	M1 (10^{-5})	2000 per cycle (950 days per cycle)

The Space Weather centres designated by the International Civil Aviation Organization (ICAO) are expected to provide airliners with advisories about anomalous conditions in HF communication when the intensity of a solar flare exceeds 10^{-4}W/m² (MOD) and 10^{-3}W/m² (SEV) (ICAO, 2019).

Key relevant UN convention / multilateral treaty

Not applicable; however, aviation-related standards fall under ICAO coordination.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Solar activity: Solar flares are associated with the active regions and sunspots on the Sun. These are often triggered by magnetic reconnection events in the solar corona. High solar activity periods characterised by increased sunspot numbers are more likely to produce solar flares.

Impacts: Radio communication disruptions: Solar flares emit intense bursts of electromagnetic radiation, including X-rays and extreme ultraviolet (EUV) radiation. These high-energy radiations can cause increased ionization in the Earth's atmosphere, particularly in the lower ionosphere. This ionization can result in increased absorption and degradation of radio waves across the HF (3-30 MHz) frequency band, affecting long-distance communications vital for aviation, maritime operations, and emergency services., leading to disruptions in radio communication.

GNSS signal interference: Solar flares can generate radio frequency interference that affects the signals transmitted by global navigation satellite systems (GNSS), such as GPS, GLONASS, BEIDOU, and GALILEO. The interference can cause inaccuracies in positioning and timing or complete loss of GNSS signals, leading to potential navigation errors for various applications, including aviation and maritime navigation.

Radio burst interference: Radio bursts from the solar flares may interfere directly with radio communication on Earth. The radio bursts may saturate ground-based mobile phone systems, aviation monitoring radars, and other transmitter/receiver systems in suitable conditions. For example, in 2015, air traffic control centres in Sweden noticed that the radar stations of the Swedish Air Navigation Service Provider were not relaying the correct data. The disruption was attributed to solar flare activity occurring near sunset in Sweden when the angle of the Sun is directed into the radar station. While the cause was rapidly identified and measures taken, the interference resulted in a 90-minute impact to radar across Swedish airspace.

The intense radiation from solar flares can damage satellites' electronic systems, disrupting communications, weather monitoring, and scientific data collection services. Increased radiation levels can also interfere with sensors and instruments aboard space-based

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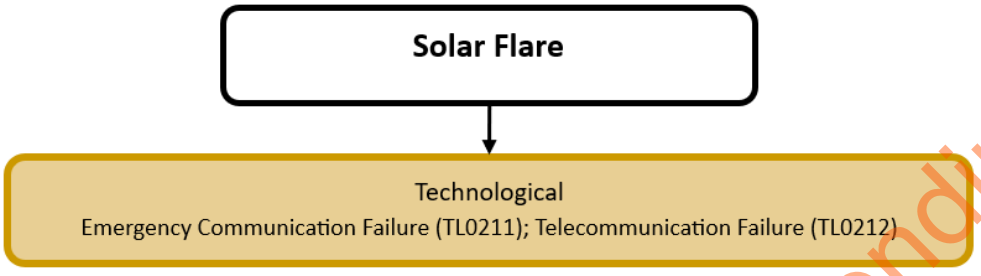
observatories.

Solar energetic particles may also pose health risks to astronauts during extravehicular activities (EVAs).

Multi-hazard Context: The figure below summarises common interactions between solar flares and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: Space weather services members of the International Space Environment Services (ISES) offer warning systems to specific users in their countries. The Space Weather centres designated by the International Civil Aviation Organization (ICAO) advise airliners about solar flares and radio fadeouts.

Risk Management: Space weather monitoring: Space weather services monitor solar activity and provide alerts and forecasts for potential solar flares. These monitoring systems help to detect and assess the risk of solar flares, allowing for appropriate risk management actions.

Radio fadeout predictions: The intensity of a solar flare can be measured using X-ray and Ultraviolet sensor data, and this information can be used to predict the potential impact on radio wave propagation. Systems like the D-Region Absorption

Backup communication systems: Organizations and industries can have backup communication systems in place to mitigate the impact of radio communication disruptions. This may involve alternative frequencies, communication modes, or redundant communication networks less affected by the ionospheric changes caused by solar flares.

GNSS integrity monitoring: GNSS users can implement integrity monitoring systems that detect and alert users to potential anomalies or interference in the GNSS signals. This allows for proactive risk management and the implementation of backup navigation methods when necessary.

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Coordinating agency or organisation

World Meteorological Organization (WMO) in collaboration with other space weather organisations.

Preliminary – Corrections Pending

ET0104 / EXTRATERRESTRIAL / Space Weather

Solar Energetic Particles

Definition

Solar energetic particle (SEP) events occur when a large-scale magnetic eruption, often accompanied by a coronal mass ejection and/or a related solar flare, accelerates charged particles in the solar atmosphere to significant fractions of the speed of light. The primary particles of interest are protons. SEP arrive with diverse fluxes and energies at different geographic locations (NOAA, 2023).

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NOAA Space Weather Prediction Center, 2023. Solar Radiation Storm. Available at https://www.swpc.noaa.gov/phenomena/solar-radiation-storm Accessed 31 January 2025.

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Preliminary – Corrections Pending

Annotations

Synonyms

Solar particle storm, Solar proton events, Solar cosmic rays.

Additional scientific description

Upon reaching Earth, the high-speed protons penetrate through the magnetosphere, which acts as a protective shield against lower-energy charged particles. Once inside the magnetosphere, the particles follow the guidance of magnetic field lines and primarily enter the Earth's atmosphere near the north and south poles. However, the more energetic particles can also reach the low-latitude upper atmosphere. SEP events can severely affect space hardware, disrupt radio communications, and cause conditions for re-routing commercial air traffic away from polar regions.

Neutron monitors can be used to record the particle flux intensity at different regions of the planet.

Metrics and numeric limits

Solar Energetic particle events are classified using a five-level scale introduced by the United States National Oceanic and Atmospheric Administration) in 1999 (NOAA, 2023). The scale is currently under review and presented below.

Scale	Description	Effect	Physical measure (Flux >= 10 MeV particles/s·ster·cm^2)	Average Frequency (1 cycle = 11 years)

S5	Extreme	Biological: Unavoidable high radiation hazard to astronauts on EVA (extra-vehicular activity); passengers and crew in high- flying aircraft at high latitudes may be exposed to radiation risk. Satellite operations: Satellites may be rendered useless, memory impacts can cause loss of control, may cause serious noise in image data, star-trackers may be unable to locate sources; permanent damage to solar panels possible. Other systems: Complete blackout of HF (high frequency) communications possible through the polar regions, and position errors make navigation operations extremely difficult.	105	Fewer than 1 per cycle
S4	Severe	Biological: Unavoidable radiation hazard to astronauts on EVA; passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk. Satellite operations: May experience memory device problems and noise on imaging systems; star-tracker problems may cause orientation problems, and solar panel efficiency can be degraded. Other systems: Blackout of HF radio communications through the polar regions and increased navigation errors over several days are likely.	104	3 per cycle
S3	Strong	Biological: Radiation hazard avoidance recommended for astronauts on EVA; passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk. Satellite operations: Single-event upsets, noise in imaging systems, and slight reduction of efficiency in solar panel are likely. Other systems: Degraded HF radio propagation through the polar regions and navigation position errors likely.	103	10 per cycle
S2	Moderate	Biological: Passengers and crew in high-flying aircraft at high latitudes may be exposed to elevated radiation risk. Satellite operations: Infrequent single-event upsets possible. Other systems: Small effects on HF propagation through the polar regions and navigation at polar cap locations possibly affected.	102	25 per cycle
S1	Minor	Biological: None. Satellite operations: None. Other systems: Minor impacts on HF radio in the polar regions.	10	50 per cycle

The Space Weather centres designated by the International Civil Aviation Organization (ICAO) are expected to provide airliners with advisories about enhanced radiation levels at flight altitudes when the dose rates due to a solar proton event exceed 30 µSievert/h (MOD) and 80 µSievert/h (SEV) (ICAO, 2019).

Key relevant UN convention / multilateral treaty

Not applicable. However, radiation exposure limits are indirectly governed by ICAO and ICRP guidelines.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Solar eruptive events: Solar energetic particle events occur during large-scale magnetic eruptions on the Sun, often associated with coronal mass ejections (CMEs) and solar flares. These events result from the acceleration of charged particles, primarily protons, to high velocities.

Impacts:

Particle exposure: Solar energetic particles, particularly high-energy protons, can pose hazards to astronauts in space and airline crew members during high-altitude flights. The increased flux of energetic particles during SEP events can lead to elevated flux levels that may exceed safety limits. Increased particle flux within the atmosphere may also impact software and hardware in aircraft avionics, causing transient or permanent malfunctions.

Satellite anomalies and failures: Solar energetic particles can cause disruptions and damage to satellites. When high-energy particles collide with sensitive electronic components onboard satellites, especially electronics and solar panels it can deteriorate or prevent communication and navigation capabilities, leading to malfunctions, data errors, or even complete satellite failures.

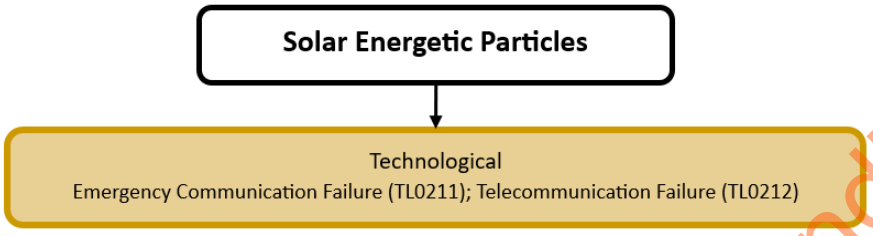
SEPs can damage satellites, particularly onboard sensors and solar arrays.

The radiation created by SEPs can increase the exposure of flight crews and passengers to radiation, leading to potential health risks and necessitating the rerouting of flights to lower latitudes. Flights on transpolar routes are the most affected and may require deviation or cancellation.

Preliminary – Corrections Pending

Particle hazards for Astronauts: Increased particle radiation doses can pose serious health risks and affect the planning and execution of space missions. Potential long-term health risks exist for populations exposed to increased levels of particle flux due to cumulative exposure during SEP events.

Multi-hazard Context: The figure below summarises common interactions between solar energetic particles and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: Space weather services members of the International Space Environment Services (ISES) provide warning systems for specific users in their countries. The Space Weather centres designated by the International Civil Aviation Organization (ICAO) give the airliners advisories about SEPs.

Risk Management: Space weather monitoring: Space weather services monitor solar activity and provide alerts and forecasts for potential SEP events. These monitoring systems help to detect and assess the risk of SEP events, allowing for appropriate risk management actions.

Particle flux forecasting: Sophisticated models and data analysis techniques are used to forecast the flux and intensity of solar energetic particles during SEP events. This allows operators of satellites and spacecraft to evaluate the potential risks and take necessary precautions to protect the systems and mitigate the impact of the radiation.

Radiation shielding: Astronauts and airline crew members are provided with radiation shielding measures, such as lead or polyethylene shielding materials, to reduce exposure to solar energetic particles during high-risk periods. Spacecraft and satellites are also equipped with shielding measures to protect sensitive components from radiation effects. Spacecraft, satellites, and planetary rovers are designed to take into account the necessary shielding to protect sensitive components from radiation effects, taking into account the foreseen radiation environment where they will operate.

Flight re-routing and altitude restrictions: During periods of heightened solar activity and SEP events, airlines and aviation authorities may consider re-routing flights away from high-polar regions or adjusting flight altitudes to reduce the exposure of crew and passengers to increased particle flux levels. ICAO's SWX advisory system helps airlines mitigate exposure by suggesting flight path alterations.

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Preliminary – Corrections Pending

Coordinating agency or organisation

World Meteorological Organization (WMO) in collaboration with other space weather organisations.

Preliminary – Corrections Pending

ET0201 / EXTRATERRESTRIAL / Space Weather

Airburst

Definition

An airburst is defined as a high-energy explosion in mid-air caused either by an artificial explosive device or by the sudden disruption of a natural object entering the Earth's atmosphere at high speeds at an altitude where the hydrodynamic pressure exceeds the structural integrity of the object (adapted from ESA, No date).

An airburst is defined as an explosion in the air, especially of a nuclear bomb or large meteorite (Lexico Dictionary, no date).

Preliminary – Corrections Pending

Reference

Lexico Dictionary, no date. Airburst. www.lexico.com/en/definition/airburst Accessed 17 December 2019.

Annotations

Synonyms

Air-blast, Fireballs, Atmospheric explosion, bolide, superbolide.

Additional scientific description

Meteoroids are objects in space that range in size from dust grains to small asteroids. Think of them as 'space rocks': when meteoroids enter Earth's atmosphere (or that of another planet, like Mars) at high speed and burn up, the fireballs or 'shooting stars' are called meteors. When a meteoroid survives a trip through the atmosphere and hits the ground, it is called a meteorite (NASA, no date).

Research has revealed why meteors explode before impacting the Earth. During model simulations of meteors entering Earth's atmosphere, air that was pushed into the meteoroid was allowed to percolate inside, which lowered the strength of the meteoroid significantly. In essence, air was able to reach the insides of the meteoroid and cause it to explode from inside out (Tabetah and Melosh, 2017; Williams, 2017).

The hazardous effects are estimated using both semi-analytical models, realised now as simple calculators, and numerical simulations of airbursts of large meteoroids and asteroids. The numerical simulations are based on the equations of hydrodynamics and radiation transfer. Dangerous consequences include shock waves with high wind speeds, fluxes of thermal radiation capable of igniting fires and causing skin burns, seismic effects of airbursts, and ionosphere disturbances. The dangerous effects of a shock wave and thermal radiation on people are considered in the context of the Chelyabinsk meteorite of 2013 and the Tunguska airburst of 1908 (Ryabova et al., 2019).

On 15 February 2013, a meteor exploded in the sky over Chelyabinsk, southern Russia. Although no people or buildings were hit by the resulting meteorite, the shockwave from the exploding object injured about 1500 people and caused damage to 7200 buildings in the region. The fireball was caught on video, mainly by dash cameras throughout the region, and posted on the internet by news organisations and individuals. Although the Chelyabinsk meteorite probably weighed about 12,000 to 13,000 tonnes and measured 17 to 20 metres in diameter before exploding, scientists were quick to point out that it was very small compared to other objects that could potentially hit the Earth. The explosion released energy estimated at about 500 kilotons of TNT (about 20 to 30 times more energy than the Hiroshima atomic bomb). The event brought to the world's attention the very real hazards associated with the impact of objects from outer space (Nelson, 2018).

In the early morning of 30 June 1908, a powerful explosion over the basin of the Podkamennaya Tunguska River (Central Siberia), devastated 2150 ± 50 km2 of Siberian taiga. Eighty million trees were thought to have been flattened, and a great number of trees and bushes were burnt in a large part of the explosion area. Eyewitnesses described the flight of a "fire ball, bright as the sun". Seismic and pressure waves were recorded in many observatories across the world. Bright nights were seen over much of Eurasia. These different phenomena, initially considered non-correlated, were subsequently linked together as different aspects of the 'Tunguska event'.

Metrics and numeric limits

Not applicable.

Key relevant UN convention / multilateral treaty

Not applicable.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Not Applicable

Impacts: The dominant hazards from airbursts consist of highly energetic shock fronts with overpressure, severe wind speeds and thermal radiation. Threat levels range from effects comparable to conventional explosives but can vary on many orders of magnitude, up to exceeding the highest levels of nuclear explosions (but without radioactivity). Natural drivers include meteoroids with velocity >11km/s, while artificial drivers include high-altitude nuclear explosions, but they have been rare since the 1963 Test Ban Treaty.

Multi-hazard Context: Not Applicable

Monitoring: Monitoring the risk of Near-Earth Objects (NEOs) capable of causing airbursts can mostly be supplied via telescopic observations of various positions of an object. Observational data is exchanged via the Minor Planet Center (MPC). The acquired positional data can be used to determine current and predict future orbits and potential impact probabilities. This activity is being executed by several agencies, such as ESA (Aegis system), NASA (Sentry system) and SpaceDyS (NEODyS system). In case of identified impact threats, the International Asteroid Warning Network (IAWN) will coordinate and aggregate information and inform decision-makers and the general public.

Risk Management: The International Asteroid Warning Network (IAWN) was established in 2013 as a result of the UN-endorsed recommendations for an international response to a potential near-Earth object (NEO) impact threat, to create an international group of organisations involved in detecting, tracking, and characterising NEOs. IAWN is tasked with developing a strategy using well-defined communication plans and protocols to assist governments in analysing asteroid impact consequences and in planning mitigation responses. Currently, IAWN includes members from Europe, Asia, South America and North America (IAWN, 2020).

IAWN has proposed the following definition: An asteroid, meteoroid, or a comet as it passes near Earth, enters the Earth's atmosphere, and/or strikes the Earth, or provokes changes in inter-planetary conditions that affect the Earth's magnetosphere, ionosphere, and thermosphere.

Criteria and thresholds related to this definition are as follows: the probability that a NEO will impact Earth (either 1% warning and 10% for terrestrial preparedness planning); the probable size, or at least its luminosity in the night sky (greater than 10 meters or at least absolute magnitude 28); and how far in the future the NEO will impact Earth (20 years).

The European Space Agency's (ESA) Space Safety Programme (S2P) partners with many countries, organisations and individuals. In particular, it has strong links with the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS), which facilitates the Space Mission Planning Advisory Group (SMPAG) and IAWN. SMPAG and IAWN were both established in response to the need for an international response to the threat of NEO impacts. SMPAG coordinates the technological know-how of agencies, including ESA, recommending specific responses to asteroid threats, including basic research and development, impact mitigation measures and deflection missions. Depending on the capabilities and specific technologies available to each agency, options are made to ensure the best use is made of the resources of each organisation. ESA's primary projects are the Space Safety Programme- especially the activities carried out by the Planetary Defence Office, such as Observation and Tracking of Near-Earth Objects (NEOs), Orbit determination and Impact monitoring and support of international mitigation activities, such as asteroid reconnaissance missions like Hera and the planned RAMSES mission to asteroid (99942) Apophis (ESA, 2025).

IAWN and SMPAG have agreed on the following criteria and thresholds for impact-response actions:

1. IAWN shall warn of predicted impacts exceeding a probability of 1% for all objects characterised to be greater than 10 metres in size, or roughly equivalent to absolute magnitude of 28 if only brightness data can be collected.

   Rationale: Impact probabilities greater than 1% are rare. Most objects greater than 10 meters in size will have effects (air blast and pieces) that could reach the Earth's surface. IAWN is compelled to warn populations if bodies will have effects that reach the ground. Setting threshold at 1% is a compromise between not being overly alarmist and not warning too late for necessary action to be initiated. It is a probability figure that individuals and governments can comprehend. An

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alert such as this demonstrates that IAWN is functioning. Further, it ensures the flow of communications from IAWN to the public and the United Nations.

2. Terrestrial preparedness planning is recommended to begin when warned of a possible impact: predicted to be within 20 years; when probability of impact is assessed to be greater than 10%; and when the object is characterised to be greater than 20 meters in size, or roughly equivalent to absolute magnitude of 27 if only brightness data can be collected.

   Rationale: Terrestrial preparedness and increased potential for impact will also involve the determination of a 'risk corridor' from objects with 10% impact probabilities and impacts in less than 20 years. This provides populations and population centres on the Earth with the information to begin preparations for emergency preparedness if needed. The surprising effects of the Chelyabinsk event in 2013 from an object ~18 meters in size, in turn led to the establishment of a lower limit (20 meters) in these threshold criteria.

3. SMPAG should start mission option(s) planning when warned of a possible impact: predicted to be within 50 years; when probability is assessed to be greater than 1%; and when the object is characterised to be greater than 50 meters in size, or roughly equivalent to absolute magnitude of 26 if only brightness data can be collected.

   Rationale: Several decades warning, if available, enables sufficient lead time to mount characterisation missions. If a 1% probability on a 100-meter object is assessed, SMPAG will be informed immediately following verification of the precise orbit. Part of such a characterisation mission would likely deploy a transponder with the object.

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Coordinating agency or organisation

International Asteroid Warning Network (IAWN) in collaboration with the European Space Agency (ESA) Space Mission Planning Advisory Group (SMPAG) and other space organisations.

Preliminary – Corrections Pending

ET0202 / EXTRATERRESTRIAL / Extraterrestrial

Ultraviolet Radiation

Definition

Ultraviolet radiation (UVR) exposure, either from the sun or from artificial sources such as sunbeds, is primarily responsible for skin cancers. Globally in 2020, over 1.5 million cases of skin cancers were diagnosed and over 120,000 skin cancer-associated deaths were reported. (WHO 2022a).

Reference

WHO 2022a. Ultraviolet Radiation World Health Organisation (WHO) https://www.who.int/news-room/fact-sheets/detail/ultraviolet-radiation Accessed 24 February 2025

Preliminary – Corrections Pending

Annotations

Synonyms

UVR, UV. UV radiation, ultraviolet light. Actinic radiation, non-ionizing UV.

Additional scientific description

Ultraviolet radiation (UVR) can neither be seen nor felt. Ultraviolet (UV) radiation covers the wavelength range of 100–400 nm, which is a higher frequency and lower wavelength than visible light. UV radiation comes naturally from the sun, but it can also be created by artificial sources used in industry, commerce and recreation (WHO no date).

The UV region covers the wavelength range of 100-400 nm and is divided into three bands:

- UVA (315-400 nm)
- UVB (280-315 nm)
- UVC (100-280 nm) (WHO no date).

As sunlight passes through the atmosphere, all UVC and approximately 90% of UVB radiation is absorbed by ozone, water vapour, oxygen and carbon dioxide. UVA radiation is less affected by the atmosphere. Therefore, the UV radiation reaching the Earth's surface is largely composed of UVA with a small UVB component (WHO no date).

The amount of UV radiation from the sun that hits the Earth's surface depends on several factors, including the sun's height in the sky, latitude, cloud cover, altitude, the thickness of the ozone layer and ground reflection. Reductions in the ozone layer due to human-created pollution increase the amount of UVA and UVB that reaches the surface. This can impact human health, animals, marine organisms and plant life. In humans, increased UV exposure can cause skin cancers, cataracts and immune system damage (WHO no date).

While some people are exposed to artificial UVR sources (e.g. in medicine, industry and for disinfection and cosmetic purposes), everyone is exposed to solar UVR. Solar UVR levels are influenced by several factors:

- Sun elevation: the higher the sun in the sky, the higher the UVR level. UVR levels vary with time of day and time of year.
- Latitude: the closer to the equator, the higher the UVR levels.
- Altitude: UVR levels increase with altitude as the air is thinner and less UVR is absorbed.
- Cloud cover: UVR levels are highest under cloudless skies but can be high even with cloud cover.
- Ozone: ozone absorbs part of the UVR from the sun. Less ozone means more UVR reaches the Earth's surface.
- Reflection: reflective surfaces, such as water, sand and fresh snow, increase the UVR level.

- Climate change, including through variations in ozone and cloud cover, is expected to impact UVR levels at the Earth's surface (WHO, 2022a).

Globally in 2020, over 1.5 million cases of skin cancers were diagnosed and over 120 000 skin cancer-associated deaths were reported (WHO 2022a).

Worldwide, it is estimated that 15 million people are blind due to cataracts; of these, some 10% may be due to exposure to UVR. (WHO 2022a).

Metrics and numeric limits

The Global Solar UV Index (UVI) is a simple measure of the UV radiation level at the Earth's surface and an indicator of the potential for skin damage. It serves as an important vehicle to raise public awareness and to alert people about the need to adopt protective measures when exposed to UV radiation. (WHO 2002)

The UVI was developed through an international effort by the World Health Organization (WHO) in collaboration with the United Nations Environment Programme (UNEP), the World Meteorological Organization (WMO), the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the German Federal Office for Radiation Protection (Bundesamt für Strahlenschutz, BfS). (WHO 2002). In summary, the risk thresholds based on UVI (WHO, 2002) are as follows:

- Low (1-2): Minimal risk; protection unnecessary.
- Moderate (3-5): Protection recommended during midday.
- High (6-7): Protection essential (e.g., sunscreen, shade).
- Very High (8-10): Extra precautions (avoid sun 10 a.m.-4 p.m.).
- Extreme (11+): Avoid all sun exposure.

This practical guide is intended to be used by national and local authorities and non-governmental organizations active in the area of skin cancer prevention, as well as meteorological offices and media outlets involved with UVI reporting. This publication can serve as an entry point for the development and implementation of an integrated public health approach to sun protection and skin cancer prevention (WHO 2002).

Key relevant UN convention / multilateral treaty

The Montreal Protocol on Substances that Deplete the Ozone Layer (UNEP, 2010a, b).

The UN Sustainable Development Goals (SDG)s, Goal 3 'Good Health and well Being' (UNEP, 2020).

The United Nations Convention on the Rights of the Child (UN, 1989).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Exposure to sunlight occupationally or for leisure is a hazard driver.

Impacts: Small amounts of UVR are essential to good health as it leads to the production of vitamin D in the body. Vitamin D strengthens the bone and musculoskeletal system. (WHO, 2022a). However, excessive exposure to UVR is associated with negative health consequences as UVR is carcinogenic to humans (WHO, 2022a). Skin cancer treatment costs exceed $8B annually in the U.S. (WHO, 2024)

Effects on the skin Acute effects of UVR include DNA damage, sunburn, phototoxic and photoallergic reactions, and suppression of the immune system. Immunosuppression can be considered as a risk factor for cancer and can cause reactivation of viruses (e.g. cold sores in the lip).

Chronic effects on skin and lips from UVR exposure include:

- cutaneous melanoma: a life-threatening malignant skin cancer;
- squamous cell carcinoma (SCC): a malignant cancer, which generally spreads less than melanoma and is less likely to cause death;
- basal cell carcinoma (BCC): a slow-growing skin cancer appearing predominantly in older people; and
- premature skin aging: a loss of skin elasticity at a young age with decreased wound healing.

Excessive exposure to UVR caused around 1.2 million new cases of non-melanoma skin cancers (SCC and BCC) and 325 000 melanomas of the skin, and 64 000 premature deaths from non-melanoma and 57 000 melanomas of the skin in the year 2020 (WHO, 2022a; IARC, 2012). In the US, in the melanoma section of the skin statistics, data suggests that each year about 6.1 million adults are treated for basal cell and squamous cell carcinomas at a cost of about $8.9 billion (CDC, 2024).

Effects on the eyes: acute effects of UVR include photokeratitis and photoconjunctivitis (inflammation of the cornea and conjunctiva, respectively). These effects are reversible, easily prevented by protective eyewear and are not usually associated with any long-term

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damage but are painful and might require therapeutic intervention.

Chronic effects of UVR include:

- cataract (an eye disease where the lens becomes increasingly opaque, resulting in impaired vision and eventual blindness);
- pterygium (growth of fleshy tissue which can cover part of the cornea); and
- cancer in and around the eye (basal cell carcinoma, squamous cell carcinoma and melanoma).

UV exposure may also be involved in the development of age-related macular degeneration (AMD).

Worldwide, it is estimated that 15 million people are blind due to cataracts; of these, some 10% may be due to exposure to UVR (WHO, 2022a).

Multi-hazard Context: UV radiation contributes to various environmental problems, such as photochemical smog formation, ozone depletion, and the degradation of pollutants and can exacerbate the impacts of other hazards such as the degradation of plastics in the environment (Menger et al, 2024), ocean warming and coral bleaching (UNEP, 2022).

Monitoring: A new app for mobile phones that provides localized information on ultraviolet (UV) radiation levels has been launched by the World Health Organization (WHO), the World Meteorological Organization (WMO), the United Nations Environment Programme (UNEP) and the International Labour Organization (ILO). The SunSmart Global UV app provides five-day UV and weather forecasts at searchable locations. It highlights time slots when sun protection is required with the aim of helping people around the world know when to use sun protection, in an effort to reduce the global burden of skin cancer and UV-related eye damage (WHO 2022 b).

The SunSmart Global UV app is available free of charge at both the Apple App and Google Play stores. It provides personalized options so that users can take action to protect prolonged, excessive UV exposure, a major cause of skin cancer and other UV-related diseases. The app allows the inclusion of national and local data streams and adaptation to multiple languages – it is currently available in Chinese, English, French, German, Russian, Dutch and Spanish (WHO 2022 b).

The app is based on the UV Index, which describes the level of solar UV radiation at the earth's surface. The UV Index is reported on a scale of 1 (or "Low") to 11 and higher (or "Extreme"). The higher the index value, the greater the potential for damage to the skin and eye, and the less time it takes for harm to occur. The maximum UV Index is at the solar noon when the sun is highest in the sky. Adapting outdoor activities and using sun protection are recommended when the UV Index is 3 or above. UV damage is cumulative, and UV can be harmful when people are exposed for long periods – even at low levels (WHO 2022 b).

The app seeks to bring worldwide consistency to UV reporting and public health messaging. It was developed by the Cancer Council Victoria and the Australian Radiation Protection and Nuclear Safety Agency, both WHO Collaborating Centres in Australia where a similar app demonstrated improved UV protection public awareness when it was used to support a decades-long, systematic public health campaign promoting sun-smart behaviour (WHO 2022 b).

Risk Management: The rise in the number of cases of skin cancer over the past decades is strongly related to increased exposure to the sun during outdoor activities and to artificial sources of UV radiation such as sunlamps and tanning beds. Overexposure is also the underlying cause of harmful effects on the eyes and immune system (WHO, 2014).

Adopting a few simple precautions can greatly reduce the risk of these health conditions:

- Limit time in the midday sun from 10 a.m. to 4 p.m., particularly on days when the UV index is high.
- When UV rays are most intense and you must be outside, try to find shade and wear protective clothing, including a brimmed hat that provides sun protection for your head, face and neck.
- Use a broad-spectrum sunscreen of at least 15 SPF – ideally higher- and reapply every 2 hours.
- Avoid sunlamps and tanning parlours, as they are known to damage the skin and eyes (WHO no date, WHO, 2024).

Children and adolescents are particularly vulnerable to the harmful effects of UVR due to their skin and eye structure. Sunburns in childhood lead to a higher risk of skin cancer in later life. Also, a larger amount of UVR can reach and damage their retina (WHO 2022a).

Fair-skinned people suffer more from sunburn and have a higher risk of skin cancer than dark-skinned people; however, darker-skinned people also develop skin cancers. Consideration of eye damage is important for everyone. People at increased risk include those with a high number of naevi, those taking photosensitizing medication, and those with a family history of skin cancer. Outdoor workers exposed occupationally to solar UVR levels face an increased risk of developing non-melanoma skin cancers (WHO 2022a).

WHO works with Member States and partners to increase public understanding of the effects of overexposure to ultraviolet radiation (WHO no date). The INTERSUN Programme is a collaboration between WHO, the United Nations Environment Programme, the World Meteorological Organization, the International Agency on Cancer Research and the International Commission on Non-Ionizing Radiation Protection. It promotes and evaluates research on the health effects of UV radiation, and develops an appropriate response

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through guidelines, recommendations and information dissemination. The goals of the programme including providing practical and sound advice on the health and environmental impacts of UV exposure, encouraging countries to take action to reduce UV-induced health risks and provide guidance to national authorities about sun awareness programmes (WHO no date). To this end, the programme collaborates with experts and specialist agencies to implement key research activities, identifies and quantifies health risks from UV radiation, develops reliable predictions of health and environmental consequences of changes in UV exposure with stratospheric ozone depletion, and develops practical ways of monitoring change in UV-induced health effects over time. The programme provides tools and guidelines related to the UV index, sun protection for children, artificial sunbeds, tourism and occupational health (WHO no date).

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WHO 2022b SunSmart Global UV App helps protect you from the dangers of the sun and promotes public health World Health Organization (WHO) https://www.who.int/news/item/21-06-2022-sunsmart-global-uv-app-helps-protect-you-from-the-dangers-of-the-sun-and-promotes-public-health Accessed 25 February 2025.

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Coordinating agency or organisation

World Health Organization (WHO), World Meteorological Organization (WMO), and other space weather organisations.

Preliminary – Corrections Pending

ET0203 / EXTRATERRESTRIAL / Extraterrestrial

Meteorite Impact

Definition

A meteorite is an object that survives a trip through Earth's atmosphere and hits the ground (adapted from NASA, no date).

Reference

NASA, no date. Meteors & Meteorites: What's the difference between a meteor, meteoroid and meteorite. Science Solar System Exploration, National Aeronautics and Space Administration (NASA). https://solarsystem.nasa.gov/asteroids-comets-and-meteors/meteors-and-meteorites/overview/?page=0&per_page=40&order=id+asc&search=&condition_1=meteor_shower%3Abody_type Accessed 14 October 2020.

Preliminary – Corrections Pending

Annotations

Synonyms

Not identified.

Additional scientific description

Meteoroids are objects in space that range in size from dust grains to small asteroids. Think of them as 'space rocks'. When meteoroids enter Earth's atmosphere (or that of another planet, like Mars) at high speed and burn up, the fireballs or 'shooting stars' are called meteors. When a meteoroid survives a trip through the atmosphere and hits the ground, it's called a meteorite (NASA, no date).

On 15 February 2013, a meteor exploded in the sky over Chelyabinsk, southern Russia. Although no people or buildings were hit by the resulting meteorite, the shockwave from the exploding object injured about 1500 people and caused damage to 7200 buildings in the region. The fireball was captured on video, mainly by dash cameras, and posted on the internet by news organisations and individuals (Nelson, 2018).

Although the Chelyabinsk meteorite probably weighed about 12,000 to 13,000 tonnes and measured 17 to 20 metres in diameter before it exploded, scientists were quick to state that it was very small compared to other objects that could potentially hit the Earth. The explosion released energy estimated at about 500 kilotons of TNT (about 20 to 30 times more energy than the Hiroshima atomic bomb). The event brought to the world's attention the very real hazards associated with the impact of objects from outer space (Nelson, 2018).

Metrics and numeric limits

Not identified.

Key relevant UN convention/multilateral treaty

Not identified.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Not Applicable

Impacts: Meteorite impacts produce an array of impact effects that can harm human populations: wind blasts, overpressure shock, thermal radiation, cratering, seismic shaking, ejecta deposition, and tsunamis. Rumpf et al. (2017) quantified the contributions of each of these effects on overall losses due to a meteorite impact of a given size in a global setting.

Small meteorite impacts, with parent bodies on the scale of no more than few metres, will have only highly localized hazard potential, essentially comprised of material falling around terminal velocities.

Decametre-sized parent objects can cause airbursts which may reach the ground and cause hazards through shock waves, overpressure and high wind speeds. In addition, larger masses can reach the ground at high speeds, causing localised explosions

upon impact.

Objects larger than about 50 metres in diameter (in addition to airburst effects) have the potential to cause sizeable craters, fully destroying the area occupied by the crater (varying with the size of an impactor) and posing further risk to the surrounding area upon impact, comparable to ground-level explosions of varying size.

Objects of sizes more than 100 metres in diameter will pose a risk to areas of tens to hundreds of kilometres and should be avoided through internationally coordinated space-based deflection efforts.

Multi-hazard Context: Not Applicable

Monitoring: Monitoring the risk of Near-Earth Objects (NEOs) capable of causing meteoritic impacts can mostly be supplied via telescopic observations of various positions of an object. Observational data is exchanged via the Minor Planet Center (MPC). The acquired positional data can be used to determine current and predict future orbits and potential impact probabilities. This activity is being executed by several agencies, such as ESA (Aegis system), NASA (Sentry system) and SpaceDyS (NEODyS system). In case of identified impact threats, the International Asteroid Warning Network (IAWN) will coordinate and aggregate information and inform decision-makers and the general public.

Risk Management: Not Applicable

References

NASA, no date. Meteors & Meteorites: What's the difference between a meteor, meteoroid and meteorite. Science Solar System Exploration, National Aeronautics and Space Administration (NASA). https://science.nasa.gov/solar-system/meteors-meteorites/ Accessed 1 April 2025.

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Coordinating agency or organisation

International Asteroid Warning Network (IAWN) in collaboration with the European Space Agency (ESA) Space Mission Planning Advisory Group (SMPAG) and other space organisations.

Preliminary – Corrections Pending

ET0204 / EXTRATERRESTRIAL / Extraterrestrial

Space Hazard / Accident

Definition

A space accident is any accident involving space objects that cause damage (adapted from UNGA, 1971).

Reference

UNGA, 1971. Resolution 2777 (XXVI). 1998th plenary meeting, 29 November 1971. United Nation's General Assembly (UNGA). www.unoosa.org/pdf/gares/ARES_26_2777E.pdf Accessed 2 April 2025.

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Annotations

Synonyms

None identified.

Additional scientific description

The term 'damage' refers to loss of life, personal injury or other impairment of health, or loss of or damage to property of States or of persons, natural or juridical, or property of international intergovernmental organisations. The term 'space objects' includes component parts of a space object as well as its launch vehicle and parts thereof (UNGA, 1971: Article I).

Space debris are all human-made objects including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional. During the operational phases, a spacecraft or orbital stage can be considered functional (IADC, 2025)

In addition, there is also the risk of damage on the ground, if debris survives Earth's atmospheric re-entry. The prompt implementation of appropriate debris mitigation measures is therefore considered a prudent and necessary step towards preserving the outer space environment for future generations (UN OOSA, 2010).

Noting concerns about an increased risk even for nominally controlled re-entries, IADC considers that if a spacecraft or orbital stage is to be disposed of by re-entry into the atmosphere, debris that survives to reach the surface of the Earth should not pose an undue risk to people or property (IADC, 2025). Using 10^{-4} as the upper limit for the expected number of human casualties per re-entry is recommended. This may be accomplished by limiting the amount of surviving debris or confining the debris to uninhabited regions, such as broad ocean areas. Also, ground environmental pollution, caused by radioactive substances, toxic substances or any other environmental pollutants resulting from on-board articles, should be prevented or minimised in order to be accepted as permissible (IADC, 2025)

The Inter-Agency Space Debris Coordination Committee (IADC) and other studies have demonstrated that accidental collisions will drive the future space debris population increase in the environment. In developing the design and mission profile of a spacecraft or orbital stage, a program or project should estimate and limit the probability of accidental collision with known objects during the spacecraft or orbital stage's orbital lifetime. If reliable orbital data and conjunction assessments are available, avoidance manoeuvres for spacecraft during all operational phases and coordination of launch windows for launch vehicle orbital stages should be considered. After the end of all operational phases of a spacecraft or orbital stage, the integrated collision risk during the remaining orbital lifetime should be minimised commensurate with post-mission disposal measures. Spacecraft design should also limit the probability of collision with small debris which could cause a loss of control, thus preventing post-mission disposal and passivation (IADC, 2025)

Spacecraft or orbital stages, in particular those that present challenges for space surveillance networks, should enhance their trackability by adding on-board active and/or passive components to the design and consider operational procedures which facilitate use thereof (IADC, 2025).

The IADC has found that observed annual rates of explosive break-ups are not compatible with limiting the space debris environment. During the design of spacecraft or orbital stages, each program or project should demonstrate, using failure mode and effects analyses or an equivalent analysis, that there is no probable failure mode leading to accidental explosive break-ups. If such failures cannot be excluded, the design or operational procedures should minimise the probability of their occurrence. The

probability of occurrence during all operational phases should be at least below 10^{-3}in order to have a noticeable effect on the space debris environment (IADC, 2025).

During the operational phases, a spacecraft or orbital stage should be periodically monitored to detect malfunctions that could lead to a breakup or loss of control function. In the case that a malfunction is detected, adequate recovery measures should be planned and conducted; otherwise, post-mission disposal and passivation measures for the spacecraft or orbital stage should be planned and conducted (IADC, 2025)

In all operational orbit regimes, spacecraft and orbital stages should be designed not to release debris during normal operations. Where this is not feasible any release of debris should be minimised in number, area and orbital lifetime. Any program, project or experiment that will release objects in orbit should not be planned unless an adequate assessment can verify that the effect on the space environment, and the hazard to other operating spacecraft and orbital stages, is acceptably low in the long-term (COPUOS, 2025)

Metrics and numeric limits

The current cumulative annual global casualty expectancy for uncontrolled re-entries of orbital stages and spacecraft is of the order of 10^{-2}. Hence, the corresponding individual risk is still extremely low, if compared with the hazards commonly faced in everyday life, with a probability of being personally injured of the order of 1 in 800 billion per year. However, this risk is increasing, due to the rapid growth of space launch activities and to the rise in world population. Moreover, during the last decades, there has been a growing consensus, at the international level, in considering a casualty expectancy of 10^{-4} as the risk limit not to be exceeded for any individual uncontrolled re-entry, while the introduction of collective risk limits is currently considered for large space systems, like mega-constellations (Pardini & Anselmo, 2024).

Key relevant UN convention / multilateral treaty

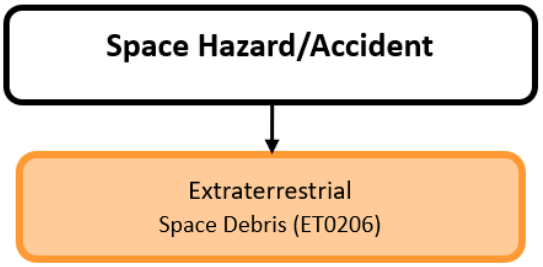
The Convention on International Liability for Damage Caused by Space Objects (Liability Convention) 1972 was considered and negotiated by the Legal subcommittee from 1963 to 1972. Agreement was reached in the General Assembly in 1971 (UNGA, 1971), and the Convention entered into force in September 1972 (UN OOSA, 1972). Elaborating on Article 7 of the Outer Space Treaty, the Liability Convention provides that a launching State shall be absolutely liable to pay compensation for damage caused by its space objects on the surface of the Earth or to aircraft, and liable for damage due to its faults in space. The Convention also provides for procedures for the settlement of claims for damages.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Spacecraft and launch vehicle orbital stages that have terminated their operational phases in orbits that pass through the LEO region should be removed from orbit in a controlled fashion. If this is not possible, they should be disposed of in orbits that avoid their long-term presence in the low earth orbit (LEO) region. When making determinations regarding potential solutions for removing objects from LEO, due consideration should be given to ensuring that debris that survives to reach the surface of the Earth does not pose an undue risk to people or property, including through environmental pollution caused by hazardous substances (UNOOSA, 2010).

Impacts: Any debris left on orbit is a hazard in view of the relative velocity with other space objects in case of collision. Therefore, restrictions, in the possible release of debris in terms of number, size, source, and risk compatibly to the state-of-the-art technology are necessary (ESA, 2023). Additionally, from a space accident, harm to spacecraft and astronauts is a risk. ESA (2017) reports that re-entry poses hazards to human health, the Earth's environment, and damages to assets associated to the re-entry of a space system, can be caused by: impacting fragments, floating fragments, pressurized or explosive fragments, hazardous chemical substances, and radioactive substances. Impacts following an accident may include ground environmental pollution, caused by radioactive substances, toxic substances or any other environmental pollutants resulting from on-board articles, should be prevented or minimised (IADC, 2025).

Multi-hazard Context: The figure below summarises common interactions between geomagnetic disturbance and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Preliminary – Corrections Pending

Monitoring: There are many national and international organisations involved in monitoring**.** As an example of monitoring, the NASA Orbital Debris Program officially began in 1979 in the Space Sciences Branch at the Johnson Space Center (JSC) in Houston, Texas. The program looks for ways to create fewer orbital debris, and designs equipment to track and remove the debris already in space (NASA, no date).

Risk Management: If a spacecraft or orbital stage is to be disposed of by re-entry into the atmosphere, debris that survives to reach the surface of the Earth should not pose an undue risk to people or property. Using 10^{-4} as the upper limit for the expected number of human casualties per re-entry is recommended. This may be accomplished by limiting the amount of surviving debris or confining the debris to uninhabited regions, such as broad ocean areas. Also, ground environmental pollution, caused by radioactive substances, toxic substances or any other environmental pollutants resulting from on-board articles, should be prevented or minimised in order to be accepted as permissible (COPUOS, 2025)

ISO 24113:2023 is the top-level standard in a family of standards addressing space debris mitigation and defines the primary space debris mitigation requirements applicable to all elements of unmanned systems launched into, or passing through, near-Earth space, including launch vehicle orbital stages, operating spacecraft and any objects released as part of normal operations (ISO, 2023).

IADC recommend that in order to limit the risk to other spacecraft and orbital stages from accidental break-ups after the completion of mission operations, all on-board sources of stored energy of a spacecraft or orbital stage, such as residual propellants, batteries, high-pressure vessels, self-destructive devices, flywheels and momentum wheels, should be depleted or made safe when they are no longer required for mission operations or post-mission disposal (IADC, 2025). Depletion should occur as soon as this operation does not pose an unacceptable risk to the payload. Mitigation measures should be carefully designed not to create other risks.

1) Residual propellants and other fluids, such as pressurant, should be depleted as thoroughly as possible, either by depletion burns or venting, to prevent accidental break-ups by over-pressurisation or chemical reaction.
2) Batteries should be adequately designed and manufactured, both structurally and electrically, to prevent break-ups. Pressure increase in battery cells and assemblies could be prevented by mechanical measures unless these measures cause an excessive reduction of mission assurance. At the end of operations battery charging lines should be de-activated.
3) High-pressure vessels should be vented to a level guaranteeing that no break-ups can occur. Leak-before-burst designs are beneficial but are not sufficient to meet all passivation recommendations of propulsion and pressurisation systems. Heat pipes may be left pressurised if the probability of rupture can be demonstrated to be very low.
4) Self-destruct systems should be designed not to cause unintentional destruction due to inadvertent commands, thermal heating, or radio frequency interference.
5) Power to flywheels and momentum wheels should be terminated during the disposal phase.
6) Other forms of stored energy should be assessed, and adequate mitigation measures should be applied (IADC, 2025)

The International Association for the Advancement of Space Safety (IAASS) is an association that seeks internationally to advance space safety through advancing the science and application of space safety. The IAASS website contains numerous resources on the topic (IAASS, no date).

Preliminary – Corrections Pending

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Coordinating agency or organisation

International Asteroid Warning Network (IAWN) in collaboration with the European Space Agency (ESA) and other space organisations.

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ET0205 / EXTRATERRESTRIAL / Extraterrestrial

Near-Earth Object

Definition

A near-Earth object (NEO) is an asteroid or comet whose trajectory brings it to within 1.3 astronomical units of the Sun and hence within 0.3 astronomical units, or approximately 45 million kilometres, of the Earth's orbit (UN OOSA, no date).

References

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Preliminary - Corrections Pending

Annotations

Synonyms

Near earth asteroid, asteroid; meteoroids.

Additional scientific description

The definition above includes objects that will come close to Earth at some point in their future orbital evolution. Near-Earth objects (NEOs) generally result from objects that have experienced gravitational perturbations from nearby planets, moving them into orbits that allow them to come near to Earth.

IAWN has proposed the following definition of a NEO: An asteroid, meteoroid, or a comet as it passes near Earth, enters the Earth's atmosphere, and/or strikes the Earth, or provokes changes in inter-planetary conditions that affect the Earth's magneto-sphere, ionosphere, and thermosphere. The criteria and thresholds related to this definition are as follows (UN OOSA, no date):

- The probability that an NEO will impact Earth (either 1% for warning or 10% for terrestrial preparedness planning).
- The probable size, or at least its luminosity in the night sky (greater than 10 meters or at least absolute magnitude 28).
- How far in the future the NEO will impact Earth (20 years).

Metrics and numeric limits

A near-Earth asteroid is said to be a potentially hazardous asteroid when its orbit comes within 0.05 astronomical units of the Earth's orbit and it has a measured absolute magnitude H<22 mag (an estimated diameter greater than 140 meters) (NASA, no date).

Key relevant UN convention / multilateral treaty

The Committee on the Peaceful Uses of Outer Space (COPUOS) was set up by the United Nations General Assembly in 1959 to govern the exploration and use of space for the benefit of all humanity: for peace, security and development (COPUOS, no date). The Committee was tasked with reviewing international cooperation in peaceful uses of outer space, studying space-related activities that could be undertaken by the United Nations, encouraging space research programmes, and studying legal problems arising from the exploration of outer space.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Not Applicable

Impacts: Near-Earth Object-related impact hazards consist primarily of the risk of airbursts and meteorite impacts.

The dominant hazards from airbursts consist of highly energetic shock fronts with overpressure, severe wind speeds and thermal

radiation. Threat levels range from effects comparable to conventional explosives but can vary on many orders of magnitude, up to exceeding the highest levels of nuclear explosions (but without radioactivity).

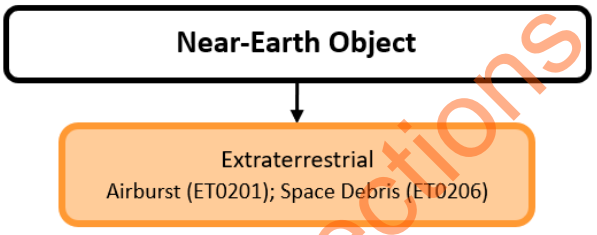
Small meteorite impacts, with parent bodies on the scale of no more than a few metres, will have only highly localized hazard potential, essentially comprised of material falling around terminal velocities.

Decametre-sized parent objects can cause airbursts which may reach the ground and cause hazards through shock waves, overpressure and high wind speeds. In addition, larger masses can reach the ground at high speeds, causing localised explosions upon impact.

Objects larger than about 50 metres in diameter (in addition to airburst effects) have the potential to cause sizeable craters, fully destroying the area occupied by the crater (varying with the size of an impactor) and posing further risk to the surrounding area upon impact, comparable to ground-level explosions of varying size.

Objects onf sizes more than 100 metres in diameter will pose a risk to areas of tens to hundreds of kilometres and should be avoided through internationally coordinated space-based deflection efforts.

Multi-hazard Context: The figure below summarises common interactions between near-Earth objects and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: Monitoring of the risk of Near-Earth Objects (NEOs) impacts can mostly be supplied via telescopic observations of various positions of an object. Observational data is exchanged via the Minor Planet Center (MPC). The acquired positional data can be used to determine current and predict future orbits and potential impact probabilities. This activity is being executed by several agencies, such as ESA (Aegis system), NASA (Sentry system) and SpaceDyS (NEODyS system). In case of identified impact threats, the International Asteroid Warning Network (IAWN) will coordinate and aggregate information and inform decision-makers and the general public.

Risk Management: The International Asteroid Warning Network (IAWN) was established in 2013 as a result of the UN-endorsed recommendations for an international response to a potential NEO impact threat, to create an international group of organisations involved in detecting, tracking, and characterising NEOs. IAWN is tasked with developing a strategy using well-defined communication plans and protocols to assist governments in the analysis of asteroid impact consequences and in the planning of mitigation responses. Currently, IAWN includes members from Europe, Asia, South and North America (IAWN, 2020).

The European Space Agency's (ESA) Space Safety Programme (S2P) partners with many countries, organisations and individuals. In particular, it has strong links with the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS), which facilitates the Space Mission Planning Advisory Group (SMPAG) and IAWN. SMPAG and IAWN were both established in response to the need for an international response to the threat of NEO impacts. SMPAG coordinates the technological know-how of agencies, including ESA, recommending specific responses to asteroid threats, including basic research and development, impact mitigation measures and deflection missions. Depending on the capabilities and specific technologies available to each agency, options are made to ensure the best use is made of the resources of each organisation. ESA's primary projects are the Space Safety Programme- especially the activities carried out by the Planetary Defence Office, such as Observation and Tracking of Near-Earth Objects (NEOs), Orbit determination and Impact monitoring and support of international mitigation activities, such as asteroid reconnaissance missions like Hera and the planned RAMSES mission to asteroid (99942).

IAWN and SMPAG have agreed on the following criteria and thresholds for impact-response actions:

1. IAWN shall warn of predicted impacts exceeding a probability of 1% for all objects characterised to be greater than 10 meters in size, or roughly equivalent to absolute magnitude of 28 if only brightness data can be collected.

   Rationale: Impact probabilities greater than 1% are rare. Most objects greater than 10 meters in size will have effects (air blast and pieces) that could reach the Earth's surface. IAWN is compelled to warn populations if bodies will have effects that reach the ground. Setting the threshold at 1% is a compromise between not being overly alarmist and not warning too late for necessary action to be initiated. It is a probability figure that individuals and governments can comprehend. An alert such as this demonstrates that the IAWN is functioning. Further, it ensures the flow of communication from IAWN to the public and the United Nations.

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2. Terrestrial preparedness planning is recommended to begin when warned of a possible impact is predicted to be within 20 years; the probability of impact is assessed to be greater than 10%; and the object is characterised to be greater than 20 meters in size, or roughly equivalent to absolute magnitude of 27 if only brightness data can be collected.

   Rationale: Terrestrial preparedness and the increased potential for impact will also involve the determination of a 'risk corridor' from objects with 10% impact probabilities and impacts in less than 20 years. This provides populations and population centres on Earth with information to begin preparations for emergency preparedness if needed. The surprising effects of the Chelyabinsk event in 2013 from an object ~18 meters in size, in turn led to the establishment of a lower limit (20 meters) in these threshold criteria.

3. SMPAG should start mission option(s) planning when warned of a possible impact predicted to be within 50 years; where the probability is assessed to be greater than 1%; and if the object is characterised to be greater than 50 meters in size, or roughly equivalent to absolute magnitude of 26 if only brightness data can be collected.

   Rationale: Several decades warning, if available, enables sufficient lead time to mount characterisation missions. If a 1% probability on a 100-meter object is assessed, SMPAG will be informed immediately following verification of the precise orbit. Part of such a characterisation mission would likely deploy a transponder with the object.

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Coordinating agency or organisation

International Asteroid Warning Network (IAWN) in collaboration with the European Space Agency (ESA) Space Mission Planning Advisory Group (SMPAG) and other space organisations.

Preliminary – Corrections Pending

ET0206 / EXTRATERRESTRIAL / Extraterrestrial

Space Debris

Definition

Space debris refers to all human-made objects, including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are nonfunctional (COPUOS, 2002 and UNOOSA, 2007).

References

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Annotations

Synonyms

Orbital Debris. Space litter

Additional scientific description

Space debris results from:

- Release during normal operations of spacecraft in outer space,
- Accidental break-ups of spacecraft during operational phases,
- Accidental collisions during operations to place spacecraft in outer space, or when spacecraft are already in outer space,
- Intentional destruction of any on-orbit spacecraft and launch vehicle orbital stages or other harmful activities that generate long-lived debris,
- Post-mission break-ups resulting from stored energy of spacecraft (UNOOSA, 2007, COPUOS, 2024).

Metrics and numeric limits

No official metrics have been defined at this time by COPUOS, UNOOSA or ITU at the international level. Some regional and national space agencies have presented some estimates of debris.

In a recent report published by the Committee on the Peaceful Uses of Outer Space (COPUOS 2024), the United Nations Office for Outer Space Affairs indicated that from 1957 to 2023, a total of 58,000 orbital objects were catalogued, with 28,000 objects remaining in orbit. Of the objects still in orbit, approximately 12,500 were satellites, while the remainder constituted rocket bodies or debris. The total mass of the objects was estimated to exceed 11,500 tons, with satellites comprising approximately 65 per cent of the total mass and rocket bodies comprising approximately 32 per cent. Approximately half of the mass was concentrated in the low Earth orbit.

The Space Debris Office of the European Space Agency (ESA) maintains a register of objects launched into outer space and data on space debris. The Office estimates that there are:

- 40,500 space debris objects greater than 10 cm
- 1,100,000 space debris objects from greater than 1 cm to 10 cm
- 130 million space debris objects from greater than 1 mm to 1 cm

Space debris also extends to the Lower Earth Orbit (LEO) where millions of pieces of debris are found. These are mostly of anthropogenic origin, such as pieces of spacecraft, flecks of paint from a spacecraft, parts of rockets, or satellites that are no longer working. These objects fly at high speed (up to 18,000 miles per hour) and together with the amount of debris present puts astronauts and equipment in space at risk. Some of the equipment at risk is essential to global communication and earth

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monitoring networks, including weather and hazard forecast and early warning systems (NASA, 2019). There are no international space laws to clean up debris in the LEO, where it is expensive to remove space debris because there are almost 6000 tons of material in LEO. The NASA Orbital Debris Program began in 1979 in the Space Sciences Branch at the Johnson Space Center in Houston, Texas. The programme looks for ways to create fewer orbital debris, and designs equipment to track and remove debris already in space (NASA, 2019).

Key relevant UN convention / multilateral treaty

Debris Mitigation Guidelines of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) (UNOOSA, 2010)

United Nations International Telecommunications Union (ITU) Recommendation ITU-R S.1003-2 (ITU, 2010)

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: The primary sources of space debris in Earth orbits have been:

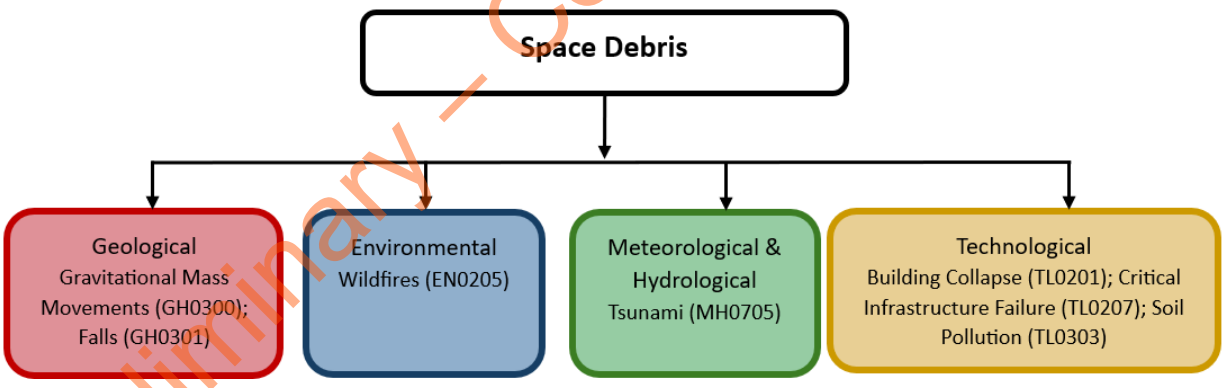
a) Accidental and intentional break-ups which produce long-lived debris and

b) Debris released intentionally during the operation of launch vehicle orbital stages and spacecraft (UNOOSA, 2007, COPUOS, 2024).

Impacts: Debris of greater dimensions than a few centimetres pose a hazard to operational satellites, the International Space Station, as well as other space stations in orbit. The hazard not only stems from the mass of the objects, but also from the relatively high speed at which debris travels in outer space with respect to satellites and space stations. Relative speeds in the order of 10 to 15 kilometres per second are typical for space debris (NASA, 2024). The European Space Agency (ESA, 2024) indicates that impacts of debris of the size of 10 cm and above on a spacecraft will most likely destroy the spacecraft.

The environmental impacts of space debris include light pollution and re-entry depositing alumina into the upper atmosphere, with changes to solar radiation that could affect the Earth's climate. In addition, there are risks of interference with communications infrastructure and functioning. It can also affect the ability to observe space.

Multi-hazard Context: The figure below summarises common interactions between space debris and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: There is no international early warning system established by the space community to address space debris. However, specific space agencies are implementing measures that have many of the elements of people-centred early warning systems.

The United States Space Surveillance Network tracks space debris, and when there is a credible threat (probability in the order of 1 in 10,000), the network will alert the International Space Station so that the station can implement manoeuvres to avoid collision (NASA, 2024).

In 2013, the European Space Agency (ESA, 2013) reported that the Consultative Committee for Space Data Standards (CCSDS) released the first standard message format for sharing collision warnings. The new standard allows space agencies from different countries or regions around the world to share warnings using standardized texts.

Risk Management: The origins of international efforts to address the challenges posed by space debris started at the end of the 1980s. These efforts stemmed from the explosion of the second stage of an Arianne 1 rocket in low-Earth orbit, creating more than 400 large pieces of debris. The Inter-Agency Space Debris Coordination Committee (IADC) was officially adopted in Moscow in October 1993. At the highest international level of the United Nations and recognizing the need to address the risk of space debris, the United Nations General Assembly endorsed the recommendation of COPUOS that the Committee's Scientific and Technical Subcommittee (STSC) consider an item on space debris (COPUOS, 2003). Since then, the topic of space debris is a regular agenda item of this Subcommittee. The Subcommittee established a dedicated working group to develop a set of recommended

Preliminary – Corrections Pending

guidelines based on the technical content and the basic definitions of the IADC space debris mitigation guidelines and, taking into consideration the United Nations treaties and principles on outer space. At the recommendation of the Sub Committee, the Committee elaborated the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space, which were endorsed by the United Nations General Assembly In its resolution 62/217 of 22 December 2007 (COPUOS, 2008).

The COPUOS guidelines for space debris mitigation are (UNOOSA, 2010):

Guideline 1: Limit debris released during normal operations: Space systems should be designed not to release debris during normal operations. If this is not feasible, the effect of any release of debris on the outer space environment should be minimized.

Guideline 2: Minimize the potential for break-ups during operational phases: Spacecraft and launch vehicle orbital stages should be designed to avoid failure modes which may lead to accidental break-ups. In cases where a condition leading to such a failure is detected, disposal and passivation measures should be planned and executed to avoid breakups.

Guideline 3: Limit the probability of accidental collision in orbit: In developing the design and mission profile of spacecraft and launch vehicle stages, the probability of accidental collision with known objects during the system's launch phase and orbital lifetime should be estimated and limited. If available orbital data indicate a potential collision, adjustment of the launch time or an on-orbit avoidance manoeuvre should be considered.

Guideline 4: Avoid intentional destruction and other harmful activities: Recognizing that an increased risk of collision could pose a threat to space operations, the intentional destruction of any on-orbit spacecraft and launch vehicle orbital stages or other harmful activities that generate long-live

Guideline 5: Minimize potential for post-mission break-ups resulting from stored energy: In order to limit the risk to other spacecraft and launch vehicle orbital stages from accidental break-ups, all on-board sources of stored energy should be depleted or made safe when they are no longer required for mission operations or post-mission disposal.

Guideline 6: Limit the long-term presence of spacecraft and launch vehicle orbital stages in the low-Earth orbit (LEO) region after the end of their mission: Spacecraft and launch vehicle orbital stages that have terminated their operational phases in orbits that pass through the Low Earth Orbit (LEO) region should be removed from orbit in a controlled fashion. If this is not possible, they should be disposed of in orbits that avoid their long-term presence in the LEO region.

Furthermore, the International Telecommunications Union launched in 2010 its Recommendation for Environmental protection of the geostationary-satellite orbit (ITU, Recommendation ITU-R S.1003-2 12/2010) https://www.unoosa.org/documents/pdf/spacelaw/sd/R-REC-S1003-2-201012-IPDF-E.pdf, Accessed 25 June 2024) outlining the following measures to minimize space debris:

Recommendation 1: That as little debris as possible should be released into the GSO region during the placement of a satellite in orbit;

Recommendation 2: That every reasonable effort should be made to shorten the lifetime of debris in elliptical transfer orbits with the apogees at or near GSO altitude;

Recommendation 3: That before complete exhaustion of its propellant, a geostationary satellite at the end of its life should be removed from the GSO region such that under the influence of perturbing forces on its trajectory, it would subsequently remain in an orbit with a perigee no less than 200 km above the geostationary altitude;

Recommendation 4: That the transfer to the graveyard orbit removal should be carried out with particular caution in order to avoid RF interference with active satellites.

Additionally, there are efforts to design space debris removal spacecraft. However, these are in the experimental stage only. Public space agencies and private companies are engaged in such efforts. To keep track of the implementation of space debris mitigation efforts, several Member States of the United Nations elaborated a Compendium of Space Debris Mitigation Standards adopted by States and International Organizations. The compendium compiles information on any legislation or standards adopted with regard to space debris mitigation. The compendium was last updated in April 2024 (UNOOSA, 2024). ITU has also implemented a dedicated webpage compiling links to guidelines, policies, legislation, best practices, and other measures implemented by international and regional organizations, and Member States of the United Nations.

Preliminary – Corrections Pending

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Coordinating agency or organisation

International Asteroid Warning Network (IAWN) in collaboration with the European Space Agency (ESA) Space Mission Planning Advisory Group (SMPAG) and other space organisations.

Preliminary – Corrections Pending

GEOHAZARDS

Preliminary – Corrections Pending

GH0101 / GEOLOGICAL / Seismic

Earthquake

Definition

Earthquake is a term used to describe the sudden slip on a fault and the ground shaking that occurs from the radiated seismic energy during the slipping event. The sudden slip can be caused by stress changes in the earth or volcanic/magmatic activity (USGS, no date).

Reference

USGS, no date. Earthquake glossary. United States Geological Survey (USGS). https://www.usgs.gov/glossary/earthquake-hazards-program#E, accessed 18 January 2025.

Annotations

Synonyms

Quake or earth tremor.

Additional scientific description

Primary earthquake hazards are those phenomena that occur most directly from an earthquake: ground shaking, surface rupture (and fissures), and subsidence/uplift. Secondary earthquake hazards are those that are caused by primary hazards and include landslides (and debris flow), liquefaction, tsunami, seiche, flooding, fire, and ground gases (Daniell et al., 2017), as well as technological and societal hazards. Usage of the term earthquake for ground shaking associated with non-seismic events (e.g. volcanic shocks that are not caused by fault movement), as well as human-induced events (e.g. nuclear explosions) is discouraged.

Metrics and numerical limits

The size or strength of an earthquake can be measured using a magnitude scale. The 'Moment magnitude' (Hanks and Kanamori, 1979) scale is one of the most common systems to measure an earthquake's size, as it quantifies the energy released by the earthquake. Magnitude scales are logarithmic, meaning that each increase of one magnitude unit (i.e., 4.3 to 5.3) corresponds to a tenfold (factor of 10) increase in the amplitude of the seismic measurements, and a factor of 32 increase in the energy release of an earthquake (USGS, no date a).

Earthquakes of magnitude 7.0 and above can be expected to cause widespread intense ground shaking as well as other triggered secondary hazards, and extensive damage Earthquakes of magnitudes 6.0 to 6.9 may cause local damage, while smaller earthquakes can cause damage to vulnerable structures at short distances. The severity and extent of earthquake damage is heavily dependent on other factors, such as the distance from the earthquake source and local conditions. Losses may be more severe and widespread for an earthquake of a given magnitude in regions of fragile buildings, high-density populations or regions with local soil conditions that cause the amplification of ground shaking.

There are many different metrics for measuring the effects of earthquakes at a particular location. Qualitative intensity measures, like the Modified Mercalli intensity (MMI) scale (Wood and Neumann, 1931), and similar scales such as the Medvedev-Sponheuer-Kárník (MSK) scale or the European Macroseismic Scale (EMS-98) describe the severity of the ground shaking on the basis of observed effects on humans, on objects and on nature, in a limited area

Preliminary – Corrections Pending

(Grünthal, 1998). Modified Mercalli intensity values range from I (Not felt) to XII (Total damage), and the threshold for seismic intensity after which structural damage is expected begins at VI, although this varies according to the vulnerability of the built environment in a given region. Since 1931, it has become clear that many of the damage phenomena described by Wood and Neumann (1931) were less related to ground shaking, and more to other factors that can cause destruction such as ground failure (Dewey et al., 1995).

Ground motion parameters related to ground shaking intensity include peak ground acceleration (PGA), peak ground velocity (PGV), and elastic spectral acceleration for a given period of vibration (SA). Most of these are commonly measured at seismic stations.

Seismic intensity and ground motion parameters can be combined with vulnerability functions and exposure datasets to calculate earthquake losses and damages (Silva et al., 2020). Some organizations have used these measures of ground shaking to quantify earthquake hazard globally such as the Global Earthquake Model (GEM) Foundation, which maintains global earthquake hazard maps (Pagani et al., 2020) or the U.S. Geological Survey that creates ShakeMaps® every time that a damaging event occurs (Wald et al., 2008).

Key relevant UN conventions and multilateral treaties

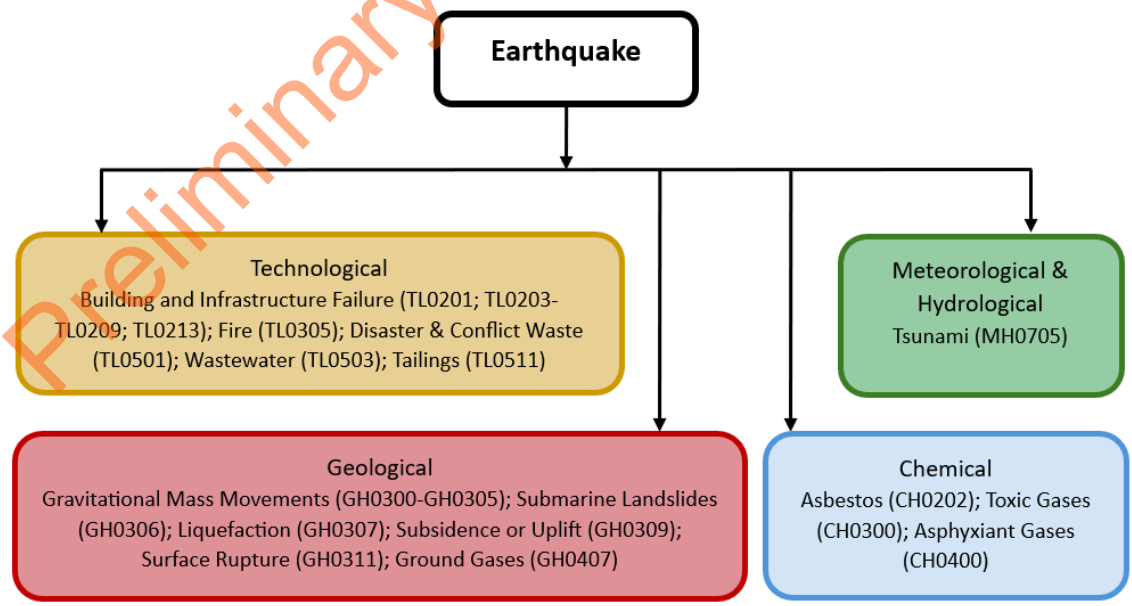
Sendai Framework for Disaster Risk Reduction 2015-2030 (UNDRR, 2015), the United Nations 17 Sustainable Development Goals.

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Earthquakes are primarily driven by natural geological processes.

Impacts: The extent of impacts commonly relates to the intensity of the earthquake, the number and intensity of aftershocks, the vulnerability of the built environment, and the time of the event. Nearly 830,000 people were killed during earthquakes and associated secondary hazardous events between 1994 and 2024 mainly due to physical (e.g., fragile building constructions) and/or social (e.g., age or health conditions) vulnerability (CRED, 2024). Impacts can be exacerbated by factors such as building construction and location of buildings (for example, structures built on soft soils), and in more vulnerable populations.

Multi-hazard Context: The figure below summarises common interactions between earthquakes and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Preliminary – Corrections Pending

Monitoring: The section and the table below offer an overview of monitoring earthquakes. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Earthquake Early Warning (EEW) systems, which trigger warnings of an earthquake in regions remote to the source, are maintained by national organisations with the remit to monitor seismic activity (e.g., USGS for the United States). For some countries, some local/urban systems also exist that are maintained by the local government.
How is the Hazard Observed/Monitored/Forecast?	The effectiveness of EEW systems is highly dependent on the quality and density of seismic networks. It is fundamental to have seismic stations/sensors relatively close to the regions where earthquakes are expected to occur (e.g., active faults), to allow sufficient lead times.

Risk Management: Earthquakes cannot be prevented (and there is no technology to reduce their magnitude). However, earthquake-related vulnerability, exposure and hence risk can be reduced through proper risk reduction measures. These can include targeted seismic retrofitting interventions, the enforcement of modern design regulations, strategic urban planning (that forbids construction near cliff faces, active faults or on soft soils), and development of risk awareness campaigns.

The most common and effective measure for mitigating earthquake risk is the implementation and enforcement of building codes with provisions for earthquake safety. The US Federal Emergency Management Agency (FEMA, 2020) and the International Association of Earthquake Engineering (IAEE) provide online resources with Seismic Building Codes. Eurocode 8 is the reference European Standard that applies to the design and construction of buildings and other civil engineering works in seismic regions.

The Global Earthquake Model Foundation recently produced a global map of earthquake hazard and risk (Pagani et al., 2020; Silva et al., 2020) and is releasing the underlying national and regional models. Many of GEM's hazard models have been developed by or in collaboration with national governments to provide a scientific basis for the development of seismic design codes.

Some success has been achieved in the development of early warning systems, which detect earthquakes close to the source or fault rupture, and trigger warnings to more distant locations, providing seconds to minutes of advance warning (Gasparini et al., 2007). Examples include the warning system for Japan's bullet trains (Tajima and Hayashida 2018) and Mexico City's warning system for evacuating occupants in vulnerable buildings (Suárez, 2022).

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Coordinating agency or organization(s)

Global Earthquake Model (GEM) Foundation.

International Association of Seismology and Physics of the Earth Interior (IASPEI).

International Association of Earthquake Engineering

Preliminary – Corrections Pending

GH0201 / GEOLOGICAL / Volcanic

Lava Flows and Domes

Definition

Lava flows and lava domes form from molten rock that erupts and cools on or near the Earth's surface. A lava flow is an outpouring of fluid, relatively low-viscosity molten rock, whereas a lava dome is a pile of relatively viscous lava that cannot flow far from the vent (cf. Dietterich et al., 2025; Harnett et al., 2025), the collapse of which may be hazardous.

References

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Harnett et al. Lava domes, Editor(s): C. Bonadonna et al., The Encyclopedia of Volcanoes (Third Edition) [Manuscript in preparation], Academic Press, 2025

Preliminary – Corrections Pending

Annotations

Synonyms

Lava effusions, Lavas.

Additional scientific description

A lava flow may comprise smaller masses of lava known as 'lava flow units', or 'lava flow lobes'; a lava flow comprising multiple lava flow units is known as a 'lava flow field'. Individual flows may branch around obstacles to create multiple flow fingers and may inflate or thicken from the original thicknesses. There are many types of lava flows. Pillow lavas are lava flows formed underwater. Fluid, subaerial lava flows may be channelized 'a'ā, lobate pāhoehoe, or blocky lavas. Lava domes may be described by their geometry. Domes are typically blocky and steep-sided and can contain uplifted solid plugs of lava (lava spines) which typically have a higher aspect ratio formed from stiffer more crystalline material. Lava coulées are a hybrid between lava domes and flows that form short, thick, viscous lava flows on a slope.

Most volcanoes erupt lava flows and/or domes during their lifetimes. Effusions of lava commonly continue from days to months, but occasionally last decades. Lava flows damage and destroy land and property but usually (not always) advance slowly enough for populations to escape. Understanding where future lava may be erupted from (the vent or vents), how far a lava flow may advance, the velocity of the flow front and the area that may be covered are critical for hazard assessments (Dietterich et al., 2025). Viscous lava domes are often crater-confined, so their flow runout typically does not destroy infrastructure. However, domes often collapse to generate very hazardous and fast-moving pyroclastic density currents (Charbonnier et al., 2025. See GH0203). The main factors controlling how a lava flow or dome develops are the rheological properties of the lava, effusion (or extrusion) rate and underlying topography.

The rheological properties of lava are influenced by chemical composition and factors such as pre- and syn-eruptive crystallization. Fluid and mobile lava flows tend to be low in silica (e.g., mafic compositions such as basalt); lava with

moderate silica content is more viscous and tends to form short blocky lava flows or lava domes (e.g., intermediate compositions such as andesite); the most silica-rich lava is most likely to form a lava dome (e.g., felsic compositions such as rhyolite). The Cordón Caulle eruption in 2011-2012, shows that rhyolitic and basaltic compound lava flows may have much in common in terms of physical processes, despite very different rheologies (Tuffen et al., 2013).

Lava flows and domes typically have a molten core, with a solid crystallized outer shell, which crystallizes with increased degassing and cooling through time. Parts of lava flows and lava domes can therefore remain molten after an eruption has ended (Dietterich et al., 2025; Harnett et al., 2025). Lava flow advance of lava dome spreading can therefore occur outside of an active eruption

Lava flow characteristics: Surface morphology of subaerial basaltic lava flows may be described as pāhoehoe (Hawaiian meaning 'smooth, unbroken') or a'ā (Hawaiian meaning 'stony, rough lava'), whereas intermediate or silica-rich lava is more likely to have a blocky surface morphology.

Models: The simplest empirical models are volcano-specific and link effusion rate to runout length, but more complex models account for cooling-induced changes in rheology as lava flows downslope. Outputs are highly sensitive to topography, as well as effusion rate and flow dynamics (Dietterich et al., 2025). High resolution digital elevation dodels are necessary but in urban and man-made environments Digital Surface Models may be more appropriate to account for the built environment.

Probabilistic hazard assessments for lava flows can anticipate inundation so are useful for long-term planning (e.g., hazard maps) and short-term forecasting (e.g., Vicari et al., 2011). However, more study is required at many volcanoes that lack important metrics such as recurrence interval, or volume of previous lava flows. New methodologies are constantly developing and generally have a two-step process: statistical analysis to establish known vent distributions and identify most likely future vent sites, followed by an estimation of the areas of inundation by lavas flowing from those vents using lava flow models (e.g., Gallant et al. 2018).

Lava flow and dome collapses: Viscous lava flows and domes may exhibit various collapse styles from persistent rock falls to partial or total collapse of a lava dome. Lava flow or dome collapse may generate pyroclastic density currents called block-and-ash flows and associated hazards such as tephra and gas emissions (Harnett et al., 2025). Lava dome collapse hazard assessments are rarely in place but are needed (Harnett et al., 2025).

Metrics and numerical limits

Basaltic pāhoehoe flows commonly have the highest eruption temperatures of 1050 to 1200°C, whereas rhyolitic lavas are typically 700-900°C (Dietterich et al., 2025). The unique 'natrocarbonatite' lava flows at Ol Doinyo Lengai volcano in Tanzania are dominated by carbonates rather than silicates and form very fluid, relatively low-temperature lavas (500-600°C) (Pinkerton et al., 1995).

At the start of an eruption, basaltic lavas may advance at several kilometres per hour, but flow velocity decreases with distance to walking pace or less within a few hours (Dietterich et al., 2025). However, flow velocity decreases less dramatically with time for long-lived eruptions. On steep slopes, some lavas may reach higher velocities of tens of kilometres per hour. Exceptionally, in 1977, lava flowed down the slopes of Nyiragongo with a maximum velocity of up to 100 km/h (Balagizi et al., 2018). Viscous lavas typically advance at rates of 0.1 km/day or less.

Basaltic lava flows typically reach lengths of 1-30 km, but occasionally more than 50 km (e.g., Mauna Loa 1859 eruption, Hawaii) (Dietterich et al., 2025). Basaltic lava flows may be 3-30 m thick and typical volumes of historical lava flows on land are between 0.01 and 1 km^3 (flow fields can exceptionally exceed 10 km^3). Intermediate and silicic lavas are usually shorter in length, typically up to 5 km but some are up to 15 km. They may be 20-300 m thick and volumes are typically 0.01 and 0.1 km3 but can be up to 10-20 km3 (Dietterich et al., 2025). If lava flows into a body of water, the interaction can form littoral explosions that deposit tephra locally, or the interaction may be passive and generate steam and formation of a lava delta.

Lava domes most commonly form in andesitic-dacitic composition but have also been observed at rhyolite volcanoes. Lava domes can grow at a range of extrusion rates (~0.01-100 m3/s) and vary in maximum volume from small lobes and spines (<0.0001 km3) to large summit domes (~0.5 km3) to enormous coulées (>5 km3), with most domes growing to ~0.001-0.2 km (Harnett et al., 2025).

Preliminary – Corrections Pending

Key relevant UN conventions and multilateral treaties

Sendai Framework for Disaster Risk Reduction 2015-2030 (UNDRR, 2015).

Examples of hazard drivers, impacts and risk management

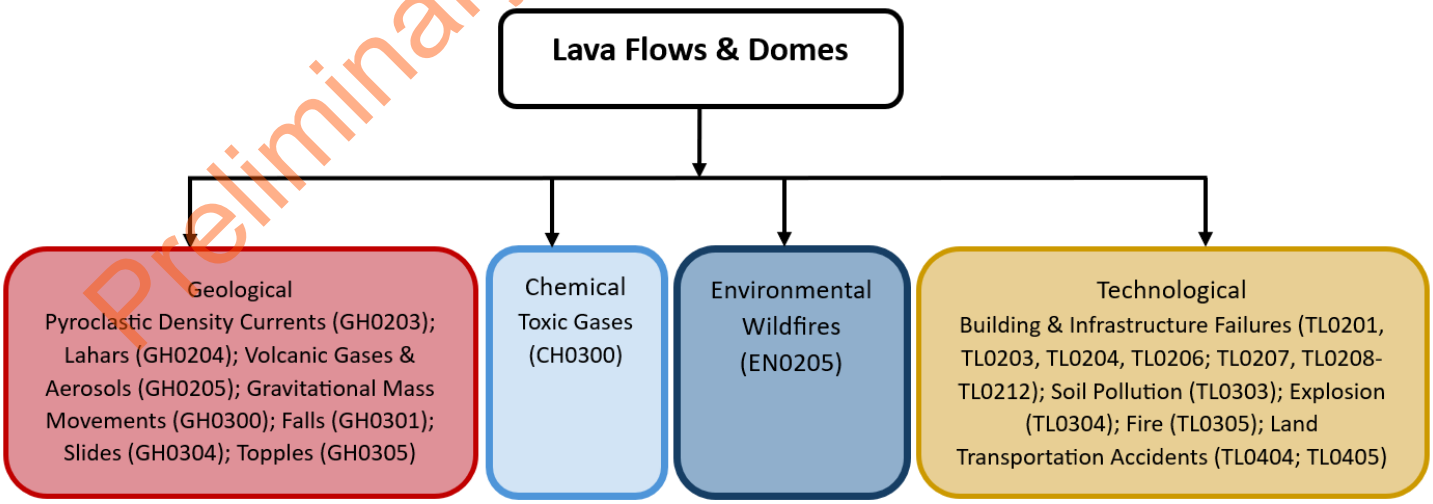
Hazard Drivers: How a lava flow or dome develops depends on various factors including the rheological properties of the lava, effusion (or extrusion) rate, underlying topography, and the morphology of the flow (for example if it flows as a broadsheet, in a confined channel or in a lava tube).

Impacts: Between 1500 AD and 2017 there were 25 documented fatal incidents, and 659 fatalities caused directly by lava flows, with fatalities occurring between 1 and 29 km of the volcanic source (median distance 11 km) (Brown et al., 2017). Fatalities and casualties occur when eruptions begin from vents close to towns and/or lavas are very fluid, on steep slopes and fast moving. For example, the 1977 eruption of Nyiragongo generated lava flows that killed about 70 people (Balagizi et al., 2018). Deaths also occur near lava entry points into the ocean, where new lava flow surfaces are unstable. Viscous lava flows and lava domes do not directly cause fatalities and injuries, but their collapse may generate pyroclastic density currents which cause more fatalities than any other volcanic hazard (Brown et al., 2017). Dome growth episodes have also been related to major explosive activity, which can have impacts on the aviation sector.

Lava flows may cause damage to buildings, infrastructure, communications, agriculture and the environment by inundation, burial, transport, fire and explosion (Jenkins et al., 2025). Damage may not be complete but partial burial or inundation by lava generally makes buildings, infrastructure and land unusable. Buried infrastructure may also be destroyed due to thermal impacts. Injuries may occur if individuals walk on a lava carapace with molten lava below. Health impacts may include burns, gas and aerosol inhalation.

Indirect impacts can include escape routes being cut off, or the lavas may trigger explosions on melting snow, ice and water, or flammable fluids. For example, in Goma in 2002, around 300,000 people self-evacuated and there were roughly 140 deaths, most caused by explosions at a petrol station that had been surrounded by lava (Balagizi et al., 2018). Lava flows may ignite forest or urban fires. Volcanic gases and aerosols (air pollution) need to be considered, possibly over large areas. Evacuation to emergency accommodation may lead to permanent displacement, which if combined with loss of livelihoods and homes, may cause longer-term mental and physical health impacts, and the long-term cascading effects can be more severe than immediate impacts (Wantim et al., 2018).

Multi-hazard Context: The figure below summarises common interactions between lava flows & domes and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring lava flows & domes. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or

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regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Volcano Observatories monitor precursory activity that could lead to hazards associated with volcanic unrest or eruption (including but not limited to ground shaking, ground fracturing, subsidence and uplift, and volcanic gases). Volcano Observatories issue warnings and, in association with civil protection and emergency management organizations, recommendations. Volcano Observatories monitor the emplacement and growth of lava flows and domes over time enabling forecasting of inundation and the anticipation of hazardous events.
How is the Hazard Observed/Monitored/Forecast?	The emplacement and growth of lava flows and domes can be observed and tracked using satellite imagery, thermal images (ground-based and remote sensing), aerial photography and visual observations. Seismometers are used to detect movement of magma in the subsurface which may lead to lava flow or dome emplacement. Numerical models are used to simulate lava dome growth and lava flow emplacement to forecast potential hazards.

Risk Management: If a volcanic area is well-monitored, the movement of magma in the subsurface may be detected days, weeks or even years before an eruption enabling planning, preparation and emergency actions such as evacuation. Effective monitoring of the emplacement of lava flows and domes over time enables forecasting of inundation and the anticipation of hazardous events such as lava dome collapse. Probabilistic hazard maps can enable appropriate land-use planning policies before eruption avoiding development in areas with a high probability of inundation (Tsang and Lindsay, 2020).

Attempts during ongoing eruptions to halt or divert flows (by erecting barriers, spraying lava with water, or breaking the margins of lava channels) have had mixed success nevertheless, in Hawaii and Iceland (2023-2024 eruptions), barriers have been constructed alongside high value assets (Tsang and Lindsay, 2020; Icelandic Meteorological Office, 2024). Evacuation remains the most effective strategy for protecting life and health from lava flow hazards (Tsang and Lindsay, 2020).

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Preliminary – Corrections Pending

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Coordinating agency or organisation

International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI)

Preliminary – Corrections Pending

GH0202 / GEOLOGICAL / Volcanic

Ash/Tephra Fall (including Volcanic Ballistic Projectiles)

Preliminary – Corrections Pending

Definition

Tephra is a collective term for volcanic fragments (pyroclasts) generated by the fragmentation of fresh magma and old (i.e., pre-existing) rocks ejected into the atmosphere during an explosive eruption, irrespective of size, composition and shape. The term 'volcanic ash' refers to the finest particles of tephra (<2 mm in diameter)(cf. Pistolesi et al. 2025).

Tephra also include relatively large bombs (fragments of fresh magma) and blocks (fragments of pre-existing rocks) that are ejected during an explosive eruption at variable velocity and angle on cannon ball-like trajectories (Volcanic Ballistic Projectiles); they are not entrained within the volcanic plume, are not significantly affected by the wind field, and are dispersed in proximity to the vent (typically <5 km) (adapted from Biass et al., 2016 and Bonadonna et al., 2021).

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Annotations

Synonyms

Pyroclasts, Ash, Lapilli, Blocks, Bombs.

Additional scientific description

Although 'volcanic ash' refers to particles less than 2 mm in diameter, the term is often used loosely to include larger fragments, more correctly termed 'lapilli' (2 to 64 mm in diameter). The largest tephra clasts (>64 mm) are called blocks and bombs. Fragments of all sizes generated during the fragmentation of magma and lava are also known as 'pyroclasts', whether they travel through the atmosphere or are directly entrained in lateral moving flows.

When blocks and bombs are not entrained within volcanic plumes and follow cannon ball-like trajectories, they are defined as volcanic ballistic projectiles (VBP). VBP may be a few centimetres to several metres in diameter and, in most cases, they sediment between a few hundred metres to 5 km from the vent. In the most powerful explosions, they can be thrown to distances over 10 km. Some large lapilli and small blocks and bombs can also be entrained within the volcanic plume and sedimented at larger distances than ballistics (Osman et al., 2019).

Along with emissions of gas, tephra is the most frequent and widespread volcanic hazard. It is ejected into the atmosphere and coupled to the gas phase remains aloft if updraft velocities exceed the gravitational settling of individual clasts. Lateral transport by wind and/or lateral gravitational spreading of umbrella clouds allows the finest particles to travel hundreds to thousands of kilometres, before eventually falling out under gravity (Pistolesi et al. 2025). Fine tephra (mainly volcanic ash) also rises convectively above pyroclastic density currents and lava fountains. Tephra can thus affect very large areas for long periods since volcanic ash can remain airborne for days causing damage to infrastructure and disruption to air traffic. Blocks and bombs mostly follow a ballistic trajectory and are not affected by wind; nonetheless, the smallest bombs can also be entrained within convective plumes impacting a larger area than ballistic clasts.

Lightning may be generated by friction between the fine airborne particles, which can be localised above the volcano or accompany large ash plumes as they move downwind.

Metrics and numerical limits

Various analytical and numerical models have been developed to forecast tephra dispersal (e.g. Folch 2012). The International Civil Aviation Organization (ICAO) leads operational forecasting of ash cloud transport for the benefit of the aviation sector (ICAO, 2012; Lechner et al., 2017).

Approximate tephra thicknesses (hazard intensities) that relate to key damage and functionality states for a range of building types, critical infrastructure and agricultural categories are given by Jenkins et al. (2015).

To assess severity at specific sites, tephra falls are most commonly described (e.g., eyewitness accounts) or measured in the field according to their thickness. Increasingly though, loading (tephra mass per unit area; kg/m^2) is more informative for assessing impact on structures and agriculture, and enables consideration of water saturation (Jenkins et al., 2015). For respiratory health exposure and hazard assessment, monitoring of airborne concentrations of fine particulates is preferable, alongside physicochemical and toxicological characterisation of the tephra particles (e.g., Horwell et al., 2013).

Various analytical and numerical models have been developed that forecast sedimentation of large lapilli and small blocks and bombs (Osman et al. 2019) and ballistic dispersal (e.g., Biass et al., 2016). Volcanic Ballistic Projectiles may be ejected at over 300 m/s but slow down during flight, with terminal velocities typically <150 m/s. Impact energy (kinetic energy at the moment of impact) is strongly controlled by the size of a VBP because this limits both its terminal velocity and mass. Alatorre-Ibargüengoitia et al. (2012) modelled impact energies of VBPs 0.2-0.6 m in diameter during small explosive eruptions (VEI 2-3) to be up to 106 J, well over the threshold required to penetrate reinforced concrete slabs (Jenkins et al., 2014).

Key relevant UN conventions and multilateral treaties

Sendai Framework for Disaster Risk Reduction 2015-2030 (UNDRR, 2015).

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Ash/tephra fall is driven by explosive volcanic activity, dependent on factors including the viscosity of the magma, volcanic gases, and conduit geometry. These control the ascent speed, decompression and degassing of the magma as it rises to the surface (Cassidy et al., 2018). Tephra fall hazard can be exacerbated by rainfall, and wind following tephra fall can result in volcanic ash resuspension, which can prolong exposure and

Preliminary – Corrections Pending

impacts (Dominguez et al. 2025).

Associated hazards include volcanic gases and aerosols (GH0205), ground gases (GH0407), toxic gases (CH300) and asphyxiant gases (CH0400) which occur simultaneously but independently of tephra fall during explosive eruptions.

Impacts: Tephra can cause fatalities directly, owing to ballistic impact, and indirectly due to the collapse of buildings (mostly roofs) and trees due to tephra load. There were 52 recorded fatal incidents as a result of tephra (not including ballistics) between 1500 AD and 2017 resulting in 4315 fatalities and these occurred between 0.5 and 170 km from the source volcano at a median distance of 10 km (Brown et al., 2017). Over the same period, there were 57 fatal incidents due to ballistics, with 367 recorded fatalities 0 to 7 km from the volcanic source (Brown et al., 2017). Fatalities have also occurred due to falling off roofs during clean-up.

In addition, public health threats, clean-up and disruption to critical infrastructure services, aviation and primary production can lead to substantial societal impacts and costs, even at thicknesses on the ground of a few millimetres. The impacts can be experienced across wide areas and can be long-lived, since eruptions can last from hours to years (IVHHN, 2021). Volcanic ash in the atmosphere can be a hazard to aviation.

The high kinetic and thermal energy of ballistics can cause damage to buildings, infrastructure, agriculture and the environment through knockdown, puncturing, crushing, burning and melting. Tourists and scientists have proven particularly vulnerable to unexpected explosive eruptions, as they tend to get close to volcanic vents. The sudden explosion of Mount Ontake, Japan, on 27 September 2014, resulted in the deaths of 58 hikers, 56 of whom were killed by ballistic rocks (Tsunematsu et al., 2016).

Large lapilli and blocks and bombs retaining sufficient thermal energy after landing can also trigger fires if they fall on ignitable material (e.g., dry vegetation and wooden structures). Intense tephra fall reduces visibility and may cause complete darkness during daylight hours, creating significant hazards for driving (tephra can also affect traction on roads and obscure road markings).

There were 57 fatal incidents due to Volcanic Ballistic Projectiles between 1500 AD and 2017, resulting in 367 recorded fatalities 0–7 km from the volcanic source (Brown et al., 2017). Many more people have been injured due to VBP impacts, frequently suffering from blunt force trauma (broken bones), lacerations, burns, abrasions and bruising (Baxter and Gresham, 1997). Large lapilli clasts falling from the margins of volcanic plumes can also result in injury and fatalities.

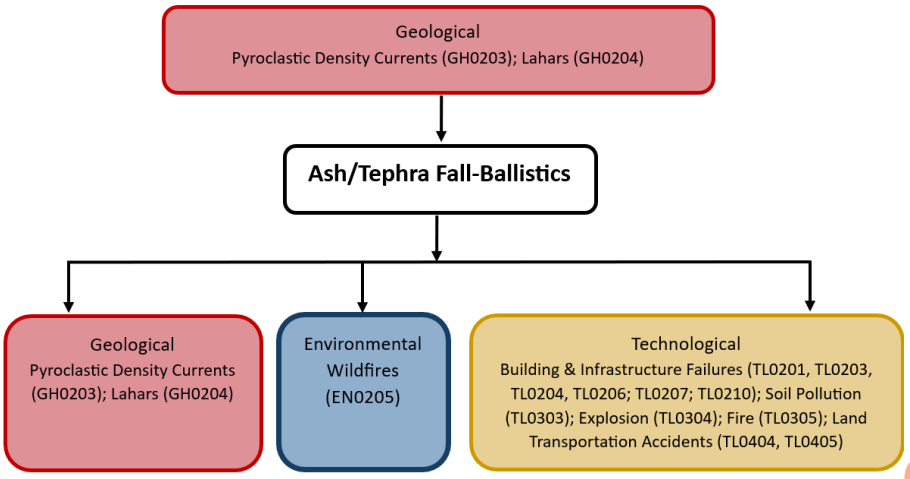
Tephra loading can damage agriculture crops, and particles can have acid coatings which may react with rain to damage vegetation and cause corrosion. The acid coating is rapidly removed by rain, which may then pollute local water supplies. Tephra can also increase river turbidity leading to environmental problems.

In most eruptions, volcanic ash causes relatively few health problems but generates much anxiety. Fine ash particles may irritate the lungs and eyes (humans and animals) and exacerbate the symptoms of existing respiratory conditions (e.g., asthma and bronchitis) (IVHHN, 2021). However, there is insufficient evidence to be certain whether ash can trigger chronic diseases such as lung cancer and silicosis (if crystalline silica is a major component) (IVHHN, 2021), and all fine particulate matter (e.g., PM2.5) is considered to negatively impact mortality and morbidity, particularly for respiratory and cardiovascular diseases (WHO, 2013).

Medical services can expect an increase in the number of patients with respiratory and eye symptoms during and after a tephra-fall event, which can be measured by existing syndromic surveillance or by application of the International Volcanic Health Hazard Network standardised epidemiological protocols (IVHHN, 2021).

Multi-hazard Context: The figure below summarises common interactions between ash and tephra fall and ballistics and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

Preliminary – Corrections Pending



Monitoring: The section and the table below offer an overview of monitoring ash and tephra falls and ballistics. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Volcano Observatories monitor precursory activity that could lead to hazards associated with volcanic unrest or eruption (including but not limited to ground shaking, ground fracturing, subsidence and uplift, and volcanic gas emissions,). Volcano Observatories issue warnings and, in association with civil protection and emergency management organizations, recommendations. Volcano Observatories use probabilistic ash dispersion models to forecast ash dispersal direction and anticipate ash/tephra fall. Warnings are issued. The International Civil Aviation Organization (ICAO) leads operational forecasting of ash cloud transport for the benefit of the aviation sector.
How is the Hazard Observed/Monitored/Forecast?	Accumulation and movement of magma in the subsurface that may lead to an explosive eruption can be monitored using a variety of instruments including seismometers, GPS, satellite imagery such as InSAR to detect deformation, thermal imaging and gas sensors (ground and satellite based). Various analytical and numerical models are used to forecast tephra dispersal.

Risk Management: As with other volcanic hazards, a combination of probabilistic volcanic hazard assessment and risk assessment combined with effective communication among scientists, emergency managers, local communities and other stakeholders can lead to effective management of risk.

A combination of field and experimental data (e.g. impact energy thresholds; Biass et al., 2016; Williams et al., 2017) are enabling building design recommendations for emergency situations, but reducing exposure to ballistics is the best risk reduction measure (Williams et al., 2017).

The fertility of the soils around many volcanoes is due to the weathering of old ash deposits, and the addition of thin tephra falls to soil can be beneficial in the long term. In many cases though, volcanic ash needs to be removed from urban and agricultural areas to prevent remobilisation and repeated impacts, as well as to prevent it from washing into drainage networks. Therefore, sites need to be identified, preferably before an eruption, to dispose of the ash. Cleaning tephra from roofs, roads, agricultural land, and critical infrastructure may require significant volumes of water, trucks, diggers, etc., and can have significant associated costs (Hayes et al., 2017).

Livestock should ideally be under cover during tephra falls and veterinary services may be needed for respiratory, ingestion, eye and dental problems.

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Coordinating agency or organisation

International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI), British Geological Survey

Preliminary – Corrections Pending

GH0203 / GEOLOGICAL / Volcanic

Pyroclastic Density Current

Definition

Pyroclastic density currents are hot, fast-moving mixtures of volcanic particles and gas that flow according to their density relative to the surrounding medium and the Earth's gravity. They typically originate from the gravitational collapse of explosive eruption columns, lava domes or lava-flow fronts, and explosive lateral blasts (cf. Charbonnier et al., 2025).

Reference

Charbonnier et al. Pyroclastic Density Currents, Editor(s): C. Bonadonna et al., The Encyclopedia of Volcanoes (Third Edition) [Manuscript in preparation], Academic Press, 2025

Preliminary – Corrections Pending

Annotations

Synonyms

Pyroclastic flow, Nuée ardente, Ash flow, Hot avalanche.

Additional scientific description

The following terms may be considered sub-types of pyroclastic density currents (PDCs): pyroclastic flow, block-and-ash flow, pumice flow, lateral blast, pyroclastic surge, pyroclastic current. The pyroclastic flow and surge are two end members (dense and dilute end, respectively). The term 'ignimbrite' is commonly used as a general term describing pumice- and ash-rich PDC deposits of very varied volumes (Charbonnier et al. 2025), but has also been used to refer, predominantly, to the large-volume end of this spectrum.

PDCs are produced from volcanic eruptions across many orders of magnitude, from small-volume events (<0.001 to 1 km^3) to very large magnitude eruptions with volumes around 10^1–10^3 km^3 of erupted material. PDCs are hot, unstoppable, gas-particle mixtures that move quickly across the ground surface at velocities of tens to hundreds of kilometres per hour and have temperatures typically between 200-600°C but can reach up to 1,000°C (Charbonnier et al. 2025). Most PDCs propagate to distances of a few to tens of kilometres from the source. Exceptionally large PDCs may travel over 100 km and cover areas of up to 10^3–10^4 km^2. Variables that can be used as hazard metrics for PDCs include flow speed, flow density, temperature, dynamic pressure, flow and deposit thickness, maximum runout, and invasion area.

PDCs comprise two different flow parts: a dense, basal undercurrent dominated by particle-particle interactions; and a dilute, upper part whose motion is mainly dominated by turbulence (Charbonnier et al. 2025). The dense basal part strongly interacts with (and is controlled by) the topographic surface as it erodes and deposits material along its path (Doronzo, 2012). The dilute upper part tends to be less controlled by topography and may decouple from the main dense undercurrent, overcoming topographic obstacles and following diverse propagation paths. Both parts can overspill their confining channels and inundate inhabited areas with differing impacts.

Metrics and numerical limits

Modelling pyroclastic density currents (PDCs) is complex due to their heterogeneous composition, three-dimensional flow over complex terrain, and the unpredictable nature of their generation and evolution. Extensive numerical modelling of PDCs has

been conducted over recent decades, to better understand PDCs and quantify their hazard (Sulpizio et al., 2014). Most past efforts have focused on simulating either the dense basal (e.g., Patra et al., 2005) or the dilute upper part of PDCs (e.g., Bursik and Woods, 1996), but several multiphase flow models have also been presented (e.g., Suzuki et al., 2005).

Key relevant UN convention and multilateral treaties

Sendai Framework for Disaster Risk Reduction 2015-2030 (UNDRR, 2015).

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Pyroclastic density currents are gravity-driven resulting from lava dome collapse (see GH0201) or collapse of an explosive eruption column.

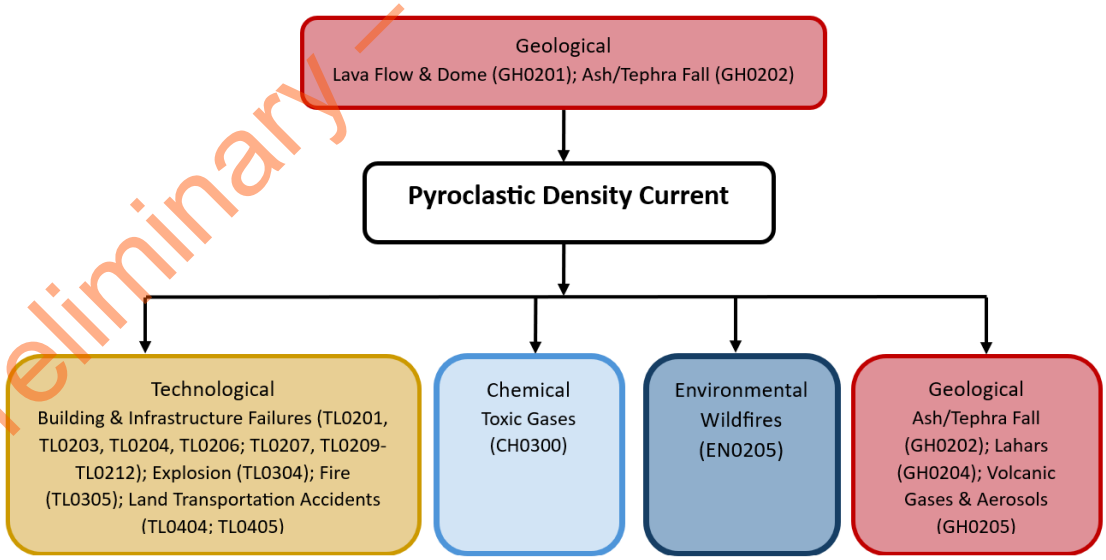
Impacts: PDCs can kill all living things and destroy structures by abrasion, impact, burial and heat. Between 1500 and 2017 AD, PDCs were the most deadly of all volcanic hazards: there were 102 fatal incidents, and 59,958 fatalities caused directly by PDCs. 50% of PDC fatalities were recorded up to 10 km from a volcano and 90% up to 20 km (Brown et al., 2017). The 1883 eruption of Krakatau volcano (Indonesia) resulted in PDC fatalities up to 80 km from the volcano, aided by the passage of PDCs over the sea (Carey et al., 1996).

Impacts on built structures rely on few empirical damage data (Cole et al., 2025 and references therein) but high-energy PDCs can sweep away buildings, with building debris then acting as missiles within the current. Dense PDCs can bury buildings and destroy their openings (windows, doors) and, dilute low-energy PDCs, with dynamic pressures of a few kilopascals or less, can cause moderate to heavy damage to buildings and initiate fires due to embers carried within the current.

Deaths commonly result from thermal injury (including laryngeal and pulmonary oedema), asphyxiation and impact or blast trauma. Survivors of PDC inundation are more likely for short-duration, slow-moving, lower temperature dilute PDCs, or those on the periphery of the flow, and for people afforded some degree of protection from the heat of the moving surge through clothing or shelter. Survivors can suffer from severe burn injuries requiring specialist treatment.

Indirect casualties can include accidents, for example, related to evacuation or unsafe driving conditions, heart attacks and cascading hazards such as fires, famine and disease. Indirect deaths can dwarf the number of direct deaths (Brown et al., 2017).

Multi-hazard Context: The figure below summarises common interactions between pyroclastic density currents and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Preliminary – Corrections Pending

Monitoring: The section and the table below offer an overview of monitoring pyroclastic density currents. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Volcano Observatories monitor precursory activity that could lead to PDC hazards associated with lava domes or explosive eruptions (including but not limited to ground shaking, ground fracturing, deformation, and volcanic gas emissions). Volcano Observatories issue warnings and, in association with civil protection and emergency management organizations, recommendations.
How is the Hazard Observed/Monitored/Forecast?	PDCs are hard to forecast, however, monitoring of lava-dome extrusion rates, and topography, can enable dome collapse PDCs to be anticipated. Hazard maps for PDCs are generated based on deposits from previous eruptions and numerical modeling which can inform likely pathways for PDCs.

Risk Management: As with other volcanic hazards, a combination of probabilistic volcanic hazard assessment and risk assessment combined with effective communication among scientists, emergency managers, local communities and other stakeholders can lead to effective management of risk. For example, In Japan, large SABO dams have been built to try and remove the heavier debris, hence energy of the flow as it moves down the volcano. Where SABO dams exist, it is possible to observe and monitor the PDC using expensive surveillance.

High resolution (spatial and temporal) monitoring of lava-dome extrusion rates, and topography, can enable dome collapse PDCs to be anticipated, resulting in timely evacuation. Probabilistic volcanic hazard assessments of PDCs are increasing in number and methods are improving.

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Coordinating agency or organisation

International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) / British Geological Survey / (BGS)

Preliminary – Corrections Pending

GH0205 / GEOLOGICAL / Volcanic

Volcanic Gases and Aerosols

Definition

Volcanic gas includes any gas-phase substance emitted by volcanic or volcanic-geothermal activity. Volcanic aerosols include liquid or solid particles small enough to be suspended in the air, that originate from volcanic gases (cf. Stix et al., 2025).

References

Stix et al. Volcanic gases and volcano degassing, Editor(s): C. Bonadonna et al., The Encyclopedia of Volcanoes (Third Edition) [Manuscript in preparation], Academic Press, 2025

Preliminary – Corrections Pending

Annotations

Synonyms

Volcanic gases: Vapours, Volatiles, Fluids, Fumes.

Aerosols: Particles, Droplets, Particulate matter, PM. Vog (a term for volcanic gas and aerosol air pollution, used mostly in Hawaii).

Additional scientific description

Volcanic gases can be emitted directly into the atmosphere from magma or by magma interacting with crustal rocks. They can be observed with spectroscopic instruments from ground and space, and their future dispersion can be modelled, allowing forecasts of gas and aerosol concentrations to be made. Volcanic gases can also be measured by direct sampling.

The chemical composition of volcanic gas and aerosol emissions is highly heterogeneous. The composition changes continuously as the emissions drift away from their source and react with the atmosphere and sunlight. Typically, the most abundant volcanic gas is water vapour (usually 80% or more of the gas mass). Other common gases are carbon dioxide (CO_2), sulphur dioxide (SO_2), hydrogen sulphide (H_2S), hydrogen (H_2) and hydrogen halides (hydrogen chloride [HCl] and hydrogen fluoride [HF]). Radon (^{222}Rn) and carbon monoxide (CO) are also emitted in trace amounts. Volcanic gases can be classified as magmatic or hydrothermal. Magmatic gases, usually rich in sulphur dioxide (SO_2) and halogens, are associated with a relatively shallow magmatic source. Hydrothermal gases result essentially from magmatic gas-heated boiling aquifers, and are richer in steam, methane (CH_4) and hydrogen sulphide (H_2S), and are virtually hydrogen chloride (HCl) and hydrogen fluoride (HF) free (Stix et al., 2025).

Volcanic aerosol sizes range from a few nanometres (nm) to several hundred micrometres (µm). Volcanic aerosol refers to particles formed through condensation of volcanic gases, or through reaction of the gases with the atmosphere and sunlight and is thereby distinct from 'ash' or 'tephra' that is formed through fragmentation of magma or lava (see GH0010). Aerosols can be in liquid or solid form and evolve between these states with time.

Volcanic gases and aerosols are emitted by almost any type of volcanic activity and from a variety of sources:

- Emissions from explosive eruptions: Depending on the explosive power, emissions can be injected into the stratosphere or stay in the troposphere and spread around the globe in the most powerful events. Typical emission duration is hours to days.
- Emissions from effusive lava eruptions, open vents and lava lakes: Emission durations can last from days up to several

decades or longer. Emissions are typically confined to the troposphere and have been instrumentally detected up to thousands of kilometres from the source.

- Emissions from medium (100–400 ºC) and high (>400 ºC) temperature fumaroles located in volcanic craters or on flanks of volcanoes. Gases are usually confined to the immediate vicinity of the source and may be sampled remotely or through direct sampling (Stix et al., 2025).
- Emissions from volcanic-geothermal systems: These low-energy and relatively low-temperature emissions (typically <100°C) are usually confined to the immediate vicinity of the source, and are usually detected through direct sampling (Stix et al., 2025).
- Emissions from soil diffuse degassing and lakes: Gases diffusely released from soils are dominated by carbon dioxide (CO_2) and commonly occur in specific areas, such as faults, small vents and steaming ground (Stix et al., 2025). However, large and highly hazardous emissions can occur if gases accumulate in the bottom of a deep lake and then rapidly release (Schmid et al., 2005). These gases may accumulate far from their source and flow down valleys as a gravity flow (Edmonds et al., 2015).

Aerosol forms by condensation of volcanic gases, both near-instantaneously after emission, and on the timescale of hours to days. Sulphate, a common aerosol component, forms through the conversion of SO_2 gas. Aerosol contains a variety of trace components, including elements collectively classified as metal pollutants by environmental and health protection agencies.

Metrics and numerical limits

The abundance of emitted volcanic gases and aerosol varies greatly among eruptions. Recent large eruptions of Holuhraun in Iceland 2014-2015 and Kīlauea (Hawaii) in 2018, emitted as much SO_2 per day as anthropogenic activities in China (50-200 kt/day) over several months (Pfeffer et al., 2018; Kern et al., 2020). A larger-scale emission scenario, which may occur in the coming decades or centuries, includes a 'Laki-type' eruption in Iceland, which can emit ten times more SO_2 than the recent eruptions described above. There are tens, or potentially hundreds, of volcanoes worldwide, which emit smaller amounts of SO_2 (0.5-5 kt/day) (Carn et al., 2016) but sustain the emissions over years -to decades (e.g., Mt Etna).

Key relevant UN conventions and multilateral treaties

Sendai Framework for Disaster Risk Reduction 2015-2030 (UNDRR, 2015).

Examples of hazard drivers, impacts and control measures of the hazard

Hazard Drivers: Volcanic gases are emitted by volcanic activity as described above; however, their release may also be triggered by surface rupture and fissuring (see GH0311). Volcanic gases and aerosols can in turn trigger hazards including (but not limited to) acid rain (see EN0105), soil pollution (see TL0303), soil degradation (see GH0402), air pollution (EN0102), critical infrastructure failure (TL0207).

For the specific cases of diffuse degassing, changes in the meteorological conditions may interfere with the flux of the gas. For instance, usually decreases in barometric pressure can increase the gas flow thereby increasing the hazard. Low barometric pressure reduces natural ventilation, which can result in increase of indoor air pollution.

Impacts: Volcanic gas and aerosol exposure are listed as the cause of 1% of total volcanic hazard fatalities (2283 people; Brown et al., 2017). This estimate includes only fatalities due to extreme direct exposure and does not include premature mortality caused by long-term air and environmental pollution. It has been estimated that 800 million people live within 100 km of a volcano that has erupted in the last 10,000 years, a range within which they could be exposed to this hazard.

Multiple chemical species in volcanic gases and aerosols may cause human and/or environmental impact (Viveiros et al., 2025) (see also Toxic gases CH0300 and Asphyxiant gases CH0400 for more details).

- Human health impacts and animals: The common effects of volcanic gases, in particular SO_2, H_2S, HCl and HF, which are poisonous, are: (i) irritation to the respiratory tract, eyes and skin; (ii) chest tightness, shortness of breath, and headaches; and (iii) asthma aggravation. SO_2 is the greatest respiratory hazard, causing health impacts, especially for asthmatics, up to thousands of kilometres from the source. High concentrations of fluoride (from HF) cause damage to teeth and bones; it is especially dangerous to grazing animals. Some gases, such as CO_2, are dangerous only if present in such a high concentration that they block oxygen respiration. All of the listed gas species, as well as CO, can cause death in high concentrations to humans and any other animals. Volcanic aerosol is typically PM2.5, an air

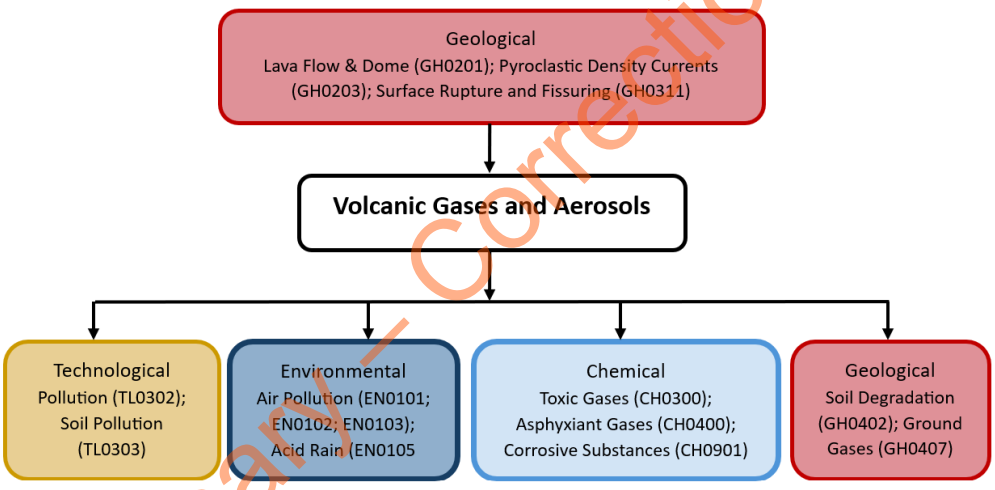
Preliminary – Corrections Pending

pollutant with no known safe exposure limits (WHO, 2021). Both acute and chronic exposure to PM2.5 causes respiratory and cardiovascular morbidity and premature mortality. More information on the health hazards and impacts of volcanic gases and aerosols can be found on the International Volcanic Health Hazard Network website (IVHHN, 2020a).

- Environmental impacts: Acid rain (see MH0033) is commonly caused by mixing of atmospheric water with volcanic gas and aerosol and leads to degradation of plant health and diversity, crop damage and damage to infrastructure. Metal pollutants can contaminate rainfall and accumulate in soils, surface waters and plants. CO_2 diffuse degassing areas may reduce plant health and diversity, and result in bare soils areas.
- Climate impacts: Large explosive eruptions can form an aerosol blanket in the stratosphere, leading to cooling at the surface which may last for months to years. For example, the 1991 Mt Pinatubo eruption lowered the surface temperature by 0.2-0.5°C, which lasted for about two years (McCormick et al., 1995).

Owing to the multiple impacts of volcanic gases, agencies in Hawaii provided a public dashboard, which summarizes the various impacts as well as providing access to monitoring and forecasting data (IVHHN, 2020b). The dashboard was accessed more than 50,000 times per week during the 2018 Kīlauea volcanic crisis. Hawaii Volcano Observatory also have a dedicated vog (volcanic gas haze) warning system.

Multi-Hazard Context: The figure below summarises common interactions between volcanic gases and aerosols and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring volcanic gases & aerosols. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Volcano Observatories monitor precursory and ongoing activity that could lead to hazards associated with volcanic unrest or eruption (including but not limited to ground shaking, ground fracturing, subsidence and uplift, and volcanic gas emissions). Volcano Observatories issue warnings and, in association with civil protection and emergency management organizations, recommendations.
How is the Hazard Observed/Monitored/Forecast?	Volcanic gas emissions can be monitored using both ground-based gas sensors and satellite data meaning that gases can be detected and tracked from space. . CO_2 in diffuse degassing areas is also permanently monitored in some diffuse degassing areas, for example in Italy, Spain (Canaries) and Portugal (Azores).

Risk Management: SO_2, particulate matter <2.5 µm in diameter (PM2.5) and, in some cases, H_2S, are volcanic gas and aerosol pollutants that are monitored and forecasted operationally by volcano observatories. Volcano observatories combine gas measurements with meteorological data and simulations to forecast gas pollution, for example, this is routinely done in Iceland. Gas pollution hazard maps are used to plan and prepare for risk management such as evacuations, road closures, and diversions.

Preliminary – Corrections Pending

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Coordinating agency or organization(s)

International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) / British Geological Survey (BGS).

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GH0300 / GEOLOGICAL / Ground Failure

Gravitational Mass Movement ('Landslide')

Definition

A gravitational mass movement ('landslide') is the downslope movement of soil, rock and organic materials under the effects of gravity, which occurs when the gravitational driving forces exceed the frictional resistance of the material resisting on the slope. Such movements may be terrestrial or submarine (GH0306) (cf. Cruden and Varnes, 1996).

Reference

Cruden, D.M. and Varnes, D.J.,1996, Landslide Types and Processes, Transportation Research Board, U.S. National Academy of Sciences, Special Report, 247: 36-75

Annotations

Synonyms

Landslide, Mass Movement, Mass wasting, Slip, Slope failure.

Additional scientific description

Gravitational mass movements occur when forces acting down-slope (mainly due to gravity) exceed the strength of the earth materials that compose the slope (Varnes, 1978). Such movements are commonly known as 'landslides'; however, many slope hazards that are referred to as such are driven by processes other than sliding. For this reason, usage of the term Gravitational Mass Movement is preferred as a broad term to encompass the wider group of slope failure mechanisms defined by Cruden and Varnes (1996). It covers movement by:

- Rock, Debris and Earth Fall (GH0301)
- Rock, Debris and Earth (mud) Spread (GH0302)
- Debris and Earth (mud) Flows and rock avalanches (GH303)
- Rock, Debris and Earth (mud) Slide (GH0304)
- Rock, Debris and Earth Topple (GH0305)

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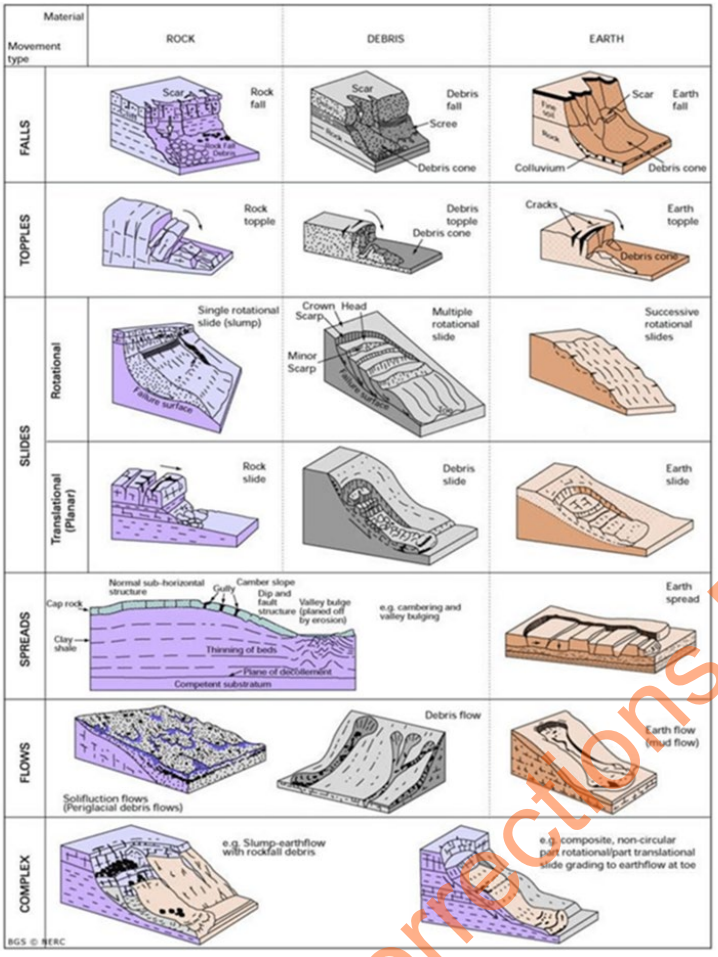

Landslide classification after Cruden and Varnes, 1996 (Taken from the web page of British Geological Survey) Accessed

Sub-categories of these are defined by the type of material (e.g., rock, soil, debris, earth, vegetation, ice), by the velocity of the mass movement (Cruden and Varnes, 1996; Hungr et al., 2014), and whether terrestrial or submarine.

Earthquake-triggered gravitational mass movements typically affect steep slopes and slopes underlain by sediments that are prone to liquefaction. Within a given region, it is possible to discriminate earthquake-triggered gravitational mass movements from those initiated by other triggering processes. For example, Lee (2012) reported that earthquake-induced gravitational mass movements in Taiwan are mostly located on steeper, longer slopes and at a higher position of the slope when compared to storm-induced shallow gravitational mass movements, suggesting that topographic amplification plays an important role in earthquake-induced gravitational mass movements. Zhang et al. (2014) compared earthquake-triggered gravitational mass movements with rainfall-triggered gravitational mass movements in the Wenchuan area of China and found that the earthquake gravitational mass movements were triggered on steeper slopes, larger gravitational mass movements dominated in areas underlain by harder bedrock compared with areas underlain by alluvium. In contrast, the rainfall-induced gravitational mass movements were characterised by a greater volume of channelled deposits and were of a higher density, but smaller area and were characterised by debris slides and debris flows. In areas that are underlain by weak bedrock that is saturated, strong earthquake-induced ground shaking will result in more gravitational mass movements than normal (Fan et al., 2019).

Volcano-triggered gravitational mass movements range in size from less than 1 km3 to more than 100 km3 in area (USGS, no date). They comprise masses of rock, soil and snow that are mobilised when the flank of a volcano collapses and moves downslope. The mobilised rock and sediment can be very destructive and entrain more sediment (as well as vegetation or structures) along its path. The high velocity and momentum allow them to cross valleys and run up slopes several hundred metres high. Larger landslides are generally more deep-seated, involving weak hydrothermal and magmatic systems in the volcano. Gravitational mass movements are common on volcanic cones because they are tall, steep, and weakened by the rise and eruption of molten rock. Magma releases volcanic gases that partially dissolve in groundwater, resulting in a hot acidic hydrothermal system that weakens rock by altering minerals to clay (USGS, no date). The gravitational mass movements leave a hummocky terrain that reflects the initial structure of the edifice (de Vries and Davies, 2015). The sediment largely comprises unsorted and unstratified angular-to-subangular debris (Siebert, 1996). Runout lengths are commonly many times the height of the volcano. Many gravitational mass movements contain or

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incorporate water that leads to secondary debris flow and lahar generation. Runout varies with the extent of air or fluid entrainment; however, the physical basis of long runouts is not fully understood. Most are the result of several factors, including volcanic flank failures. Gravitational mass movements on volcanic islands such as Hawaii, Reunion and Tristan da Cunha are characterised by long runout distances and volumes exceeding 1000 km^3 (Hürlimann et al., 2000).

Metrics and numerical limits

Gravitational mass movements are largely measured by volume, runout distance, or the area of disturbed ground from which material has moved downslope and, or where it has accumulated following movement.

Gravitational mass movements may also be measured based on their velocity. Movements range from extremely slow (16 mm/yr) to extremely rapid (5 m/sec) (Cruden and Varnes, 1996). For example, the mass movement at Mount St. Helens on 18 May 1980, with a volume of 2.5 km^3, reached speeds of 50-80 m/s, with the energy to surge up and over a 400-m-tall ridge located about 5 km from the volcano (de Vries and Davies, 2015). Submarine gravitational mass velocity movements have been measured in two events from the breakage of submarine telephone cables. These indicate velocities of up to 28 m/s or 101 km/h (Grand Banks, 1929) and 5 to 16 m/s (18-57 km/h) in the Strait of Luzon between Taiwan and the Philippines between 2006 and 2015.

Key relevant UN conventions and multilateral treaties

Not identified.

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Gravitational mass movements, whether terrestrial or submarine, can be triggered by multiple sources including earthquakes, volcanic activity, storms, high precipitation, differential weathering (e.g., freeze/thaw) and human activity. These mass movements can in turn trigger tsunamis and can have multiple associated hazards including ground fracturing and ground gases (HIP ref).

The fundamental geological, geomorphological, and hydrological conditions are significant underlying factors contributing to gravitational mass movements. Soil and rock types, such as weak rock strata (e.g., shale and mudstone) or loose sediments (e.g., clay and loess), are more prone to sliding. Tectonic activities render slopes with well-developed faults and joints more unstable. Prolonged rainfall, intense downpour or rapid snowmelt can increase pore water pressure and soften the soil and rock, thereby facilitating landslides.

Gravitational mass movements are usually triggered in steep slopes but can also occur in shallow slopes. These slopes are commonly underlain by sediments such as weakly cemented rocks, more indurated rocks with pervasive discontinuities, residual and colluvial sand, volcanic soils with sensitive clays (e.g., Iburi-Tobu earthquake, Hokkaido; Kameda et al., 2019), glaciomarine soils with sensitive clays (e.g., Norway, Sweden, St. Lawrence Lowlands of Canada), loess, alluvium and deltaic deposits.

Impacts: Gravitational mass movements can be extremely destructive, especially when failure is large, sudden and (or) the velocity is rapid. According to the World Health Organisation, between 1998-2017 gravitational mass movements affected an estimated 4.8 million people and caused over 18,000 deaths (WHO, 2025). Deaths are caused by the burial of towns or villages or disruption of foundations and subsequent collapse of buildings.

The Mount St. Helens eruption was triggered by gravitational mass movement as a consequence of the structural instability of the volcano. The eruption caused the death of 57 people, 53 through direct impacts including asphyxiation, thermal injuries, and trauma. Snowmelt led to extensive river flooding (Oregon State University, 2020).

Gravitational mass movement impacts can cascade to dam rivers and impound lakes, which can collapse days to centuries later. They can cause extensive mountain valley flooding and leave a geomorphology that may be prone to remobilisation during heavy rainfall, potentially evolving as debris flows. Cracks and fractures can form and widen on mountain crests and flanks, conditioning the landscape for an increased frequency of mass movements that lasts for decades. Increased debris load delivery to rivers can cause bank erosion and floodplain accretion as well as stream channel switching that affects flooding frequency, settlements, ecosystems, and infrastructure (Fan et al., 2019). In coastal and offshore regions, submarine mass movement impacts threaten submarine installations such as oil platforms, pipelines, cables, and wind installations, through destabilization of the seabed or breakage of cables.

While the physical damage of slope hazards is wel documented, health impacts are complex. The risk of an increase in infectious diseases is of concern during the response and recovery phase after any major disaster. Displacement of people due to the destruction of their homes and other infrastructure can place them in unfamiliar surroundings which, if they conflict with traditional beliefs and practices with regard to water supply and hygiene, can result in unsafe behaviours. The medium- to long-term effects of changes to the environment caused by mass movements, such as deforestation, and changes to river courses, can increase the risk of vector-borne diseases, and as a result, the health impacts can extend

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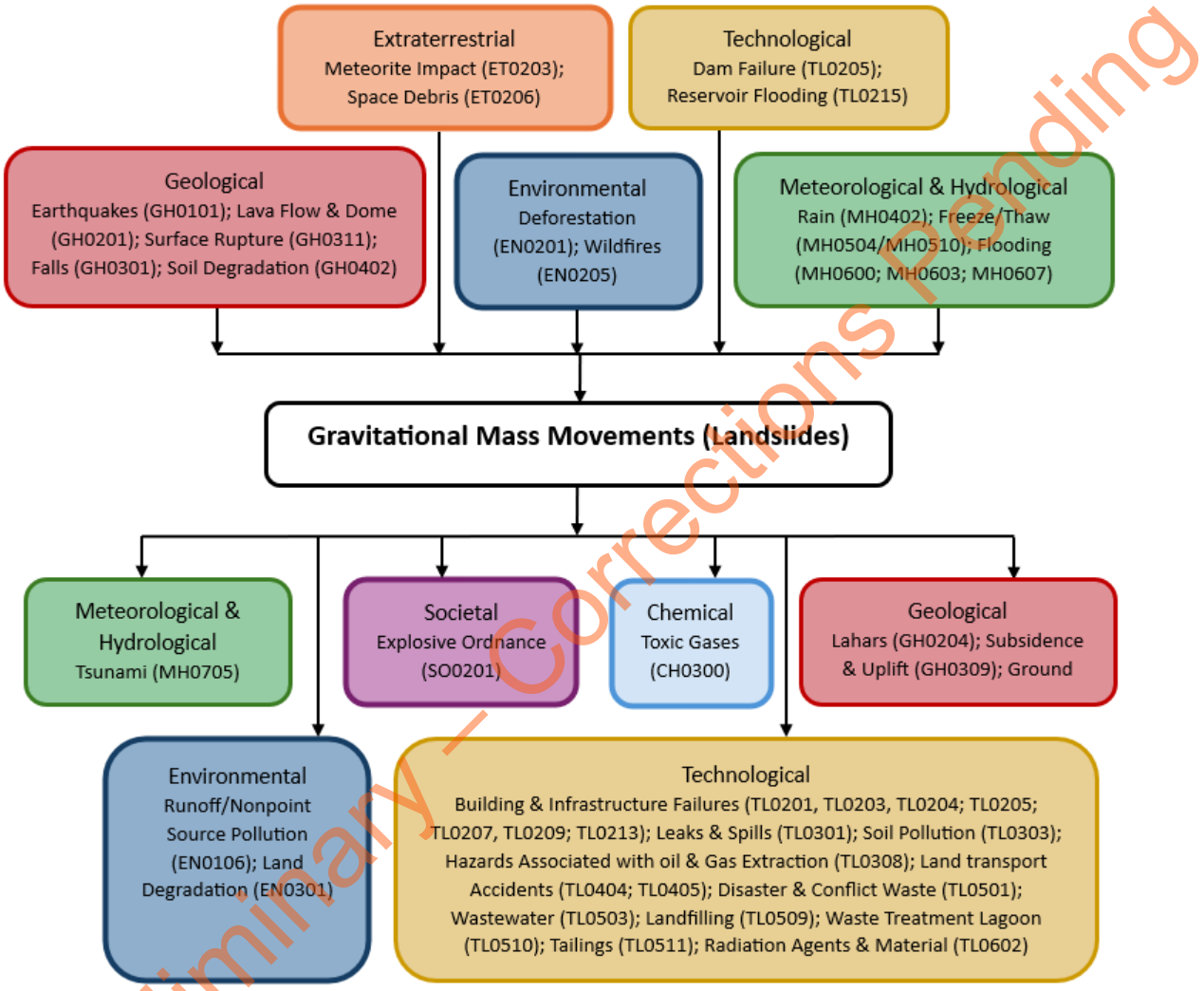
long after the initial disaster is over. Disruption of soil can also increase exposure to infectious organisms (Kennedy et al., 2015). The psychosocial and mental health impacts on survivors and rescue personnel from mass movements are increasingly recorded. The prevalence of psychiatric disorders and wider support needed to reduce misuse of substances has been identified (Kennedy et al., 2015; Dell'Aringa et al., 2018).

Multi-hazard Context: The figure below summarises common interactions between gravitational mass movement (landslide) and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



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Monitoring: The section and the table below offer an overview of monitoring gravitational mass movement (landslide). This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Local Authorities, Geological Surveys may produce disaster risk data/information
How is the Hazard Observed/Monitored/ Forecast?	Instrumental monitoring to detect movement and the rate of movement can be implemented, for example, extensometers, inclinometers, global positioning system (GPS), seismometers, aerial photography, satellite images, LiDAR.

Risk Management: In terms of natural hazards, the Encyclopaedia of the Environment reported two categories of protection: active protections to remove the hazard itself and passive protections, which do not seek to oppose natural phenomena only to limit their harmful consequences for developments (buildings, communication routes) (Dennis and Didier, 2019).

- *Active protections* are diverse and include (i) general methods, such as surface or deep drainage, and slope vegetation that limits erosion due to runoff (gully excavation) and infiltration that alters mechanical properties (friction, cohesion of rock joints); (ii) supports, such as retaining walls, rock bolts or anchored mesh covered with sprayed concrete; (iii) wire mesh (draped or pinned), i.e., metal structures designed to contain the massif and prevent the spread of falling rocks and blocks; (iv) scaling/mining, which are radical solutions that comprise removing unstable elements, although these solutions are not always as definitive as expected (the continuous alteration and the blast vibrations are often harmful to the stability of the surrounding massifs); and (v) regrading/ reprofiling can be designed to reduce the landslide driving forces (Dennis and Didier, 2019).
- *Passive protections* are also diverse: (i) barriers and dikes are gabions or concrete blocks placed at the foot of unstable slopes; their purpose is to stop the propagation of rock elements before reaching the stakes; their location, which requires sufficient space and their dimensioning, takes into account the properties of the materials that constitute them, but first of all numerical simulations that are made to model the propagation of blocks (trajectory circulations); (ii) the diverters are also embankments; installed on the slope, they divert the flow of the elements towards a space without stakes; (iii) protection galleries, similar to avalanche tunnels, are likely to protect communication routes when crossing corridors; (iv) rigid fences are placed on steep slopes as close as possible to the starting areas; their installation is often difficult to achieve; and (v) deformable wire-mesh can be placed lower on the slopes until they are close to the issues at stake; the most well-known case is the use of 'submarine' type nets (used during the Second World War to prevent the penetration of ports by submarine vehicles) stretched between rigid poles and maintained by fusible carabiners; this device is thus calculated to resist an impact energy previously determined in the study of randomness and its propagation (Dennis and Didier, 2019).

The appropriate responses to reduce the risks associated with rock instabilities are effective but often require a large budget. It is not viable to consider eliminating risk wherever it exists. The best protection is always based first on geological reconnaissance, planning, and the use of preventative actions such as drainage or regular purging of unstable elements, and monitoring based on measurements when movements are detected. Such monitoring often triggers an alert with a road closure or evacuation of an inhabited area (Dennis and Didier, 2019).

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Coordinating agency or organisation

British Geological Survey / Geological Survey of Canada

Preliminary – Corrections Pending

GH0301 / GEOLOGICAL / Ground Failure

Rock, debris and earthfalls

Definition

A rock, debris or earthfall is a fragment of rock (a block), body of debris or earth (here taken to include mud) detached by sliding, toppling, or falling, that falls from a vertical or sub-vertical cliff and proceeds downslope by bouncing and flying along ballistic trajectories or by rolling on talus or debris slopes (adapted from Highland and Bobrowsky, 2008).

Reference

Highland, L.M. and P. Bobrowsky, 2008. The Landslide Handbook – A guide to understanding landslides. U.S. Geological Survey Circular 1325.

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Annotations

Synonyms

Rockfall (Varnes, 1978), Rock free fall, Block fall, Boulder fall.

Additional scientific description

Falls are abrupt, downward movements of rock or earth, or both, that detach from steep slopes or cliffs. The falling material usually strikes the lower slope at angles less than the angle of fall, causing bouncing. The falling mass may break on impact, may begin rolling on steeper slopes, and may continue until the terrain flattens (Sassa et al., 2018). Materials from falls sometimes generate flows (HIP Ref) such as avalanches.

Metrics and numerical limits

Very rapid to extremely rapid, free-fall, bouncing and rolling of detached soil, rock, and boulders. The rolling velocity depends on slope steepness (Hungr et al., 2014).

Key relevant UN conventions and multilateral treaties

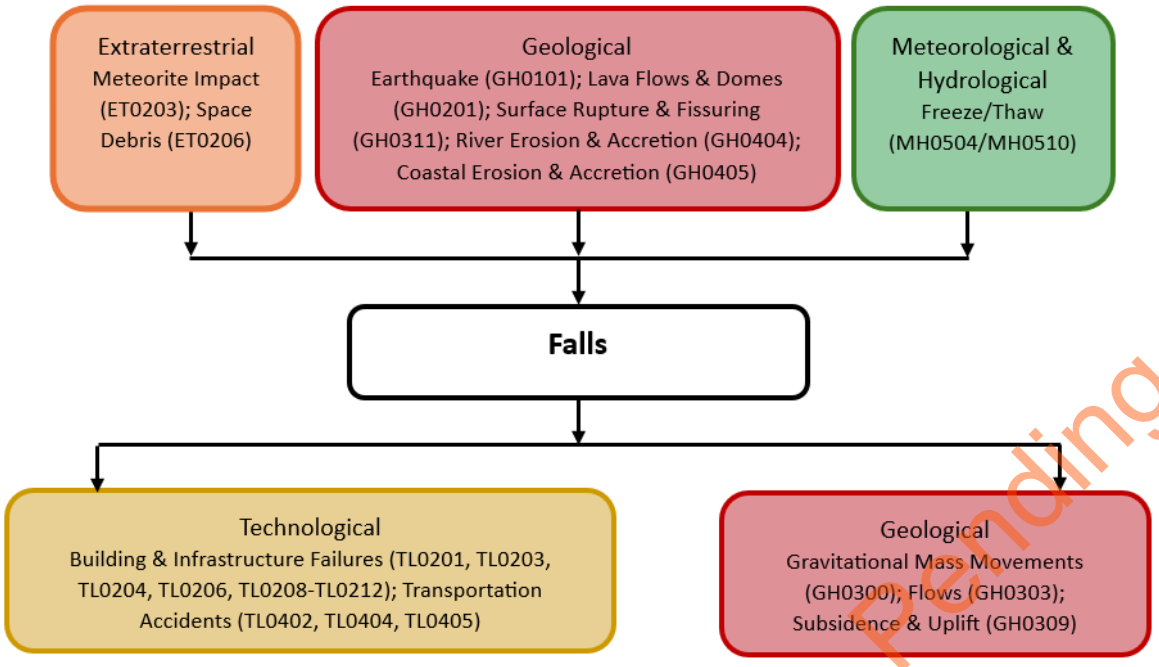
Not applicable.

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Drivers for rockfall include undercutting of slopes by natural processes such as streams and rivers or differential weathering (such as the freeze/thaw cycles and heave and desiccation cycles related to sustained high temperatures), human activities such as excavation during road building and (or) maintenance. Volcanic activities and earthquake shaking or other intense vibrations are also drivers for rockfall (Hungr et al., 2014).

Impacts: Falling material can be life-threatening. Falls can damage property beneath the fall line of large rocks. Boulders can bounce or roll great distances and damage structures or kill people. Damage to roads and railroads is particularly high: rockfalls can cause deaths in vehicles hit by rocks and can block highways and railroads (Highland and Bobrowsky, 2008).

Multi-hazard Context: The figure below summarises common interactions between falls and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring spreads. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Local Authorities; Geological Surveys may produce disaster risk data/information
How is the Hazard Observed/Monitored/Forecast?	Slopes or cliffs that falls may detach from can be monitored via satellite imagery, InSAR, and visual observations, among others.

Risk Management: Mitigation measures for rockfall include rock curtains or other slope covers, protective covers over roadways, retaining walls to prevent rolling or bouncing, explosive blasting of hazardous target areas to remove the source (scaling), removal of rocks or other materials from highways and railroads can be used to minimise risk (Sassa et al., 2018).

Rock bolts or other similar types of anchoring used to stabilise cliffs, as well as scaling, can lessen the hazard. The removal of loose boulders can also lessen the hazard. Warning signs are recommended in hazardous areas for awareness. Stopping or parking under hazardous cliffs should be warned against (Highland and Bobrowsky, 2008).

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Coordinating agency or organisation

British Geological Survey, Geological Survey of Canada

Preliminary – Corrections Pending

GH0302 / GEOLOGICAL / Ground Failure

Rock, debris and earth spreads (including landscape creep)

Definition

Rock spread: Near-horizontal stretching (elongation) of a mass of coherent blocks of rock as a result of intensive deformation of an underlying weak material, or by multiple retrogressive sliding controlled by a weak basal surface. Usually with fairly limited total displacement and slow movement (Hungr et al., 2014).

Debris spread requires formal definition but is likely to include sub-categories based on the type of material and the velocity of the mass movement (cf. Cruden and Varnes, 1996; Hungr et al., 2014). It includes *Sand/silt liquefaction spread*: extremely rapid lateral spreading of a series of soil blocks, floating on a layer of saturated (loose) granular soil, liquefied by earthquake shaking or spontaneous liquefaction (Hungr et al., 2014).

Earth spread requires formal definition but is likely to include sub-categories based on the type of material and the velocity of the mass movement (cf. Cruden and Varnes, 1996; Hungr et al., 2014). It includes *Sensitive clay spread*: extremely rapid lateral spreading of a series of coherent clay blocks, floating on a layer of remoulded sensitive clay (Hungr et al., 2014).

Preliminary – Corrections Pending

Reference

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Annotations

Synonyms

Cambering, creep, solifluction

Additional scientific description

Spreads are tensional features that are susceptible to changes in their geotechnical properties at the stratal boundary, commonly

at low angles of dip. They manifest as an extension of cohesive soil or rock mass, commonly combined with subsidence. Typically, subsidence may occur because of liquefaction, suffosion, tectonic spreading, uplift, or hydrological change leading to creep or deep erosion, which may be naturally occurring or due to anthropogenic activity. Related phenomena can include the formation of fractures, gulls and lineations.

In rock spreads, solid ground extends and fractures, pulling away slowly from stable ground and moving over the weakened layer without necessarily forming a recognisable surface of rupture. The softer, weaker unit may, under certain conditions, squeeze upward into fractures that divide the extending layer into blocks. In earth spreads, the upper stable layer extends along a weaker underlying unit that has flowed following liquefaction or plastic deformation. If the weaker unit is relatively thick, the overriding fractured blocks may subside into it, translate, rotate, disintegrate, liquefy, or even flow.

Spreads can also be triggered in sensitive clays (also called quick clays or Leda clays) and involve the rapid translation and dislocation of a coherent soil mass in blocks in the form of horst and graben found above a weak horizon of remoulded, i.e., liquefied, sensitive clay (Cruden and Varnes, 1996; Hungr et al., 2014). When the soil mass completely liquefies, it will flow, which is then termed a flowslide (Hungr et al., 2014). In either case, the failure is retrogressive, meaning that the mass movement mainly progresses upslope (Richer et al., 2020). Such slope failures have been observed in the northern hemisphere in Scandinavian countries and in the USA (e.g., Alaska, Maine).

Spreads in sensitive clays usually subside in the form of a crater downslope leaving intact blocks of material within the crater. If the sediment completely liquefies, the crater is emptied as the sediment flows outside (Richer et al., 2020).

Landscape creep is the slow downward movement of slope-forming soil or rock, typically less than 1 m deep. Movement is caused by shear stresses that are sufficient to produce permanent deformation, but too small to produce shear failure (adapted from Hutchinson, 1968; Varnes, 1978). Three types of creep are recognised: within the depth affected by seasonal change in soil moisture and temperature; continuous where shear stress continuously exceeds material shear strength; and progressive where slopes are reaching the point of failure for other mass movement failure processes.

Solifluction in permafrost zones represents the slow mass-wasting associated with freeze-thaw action whilst the saturated soil movement associated with ground thawing is gelifluction (Washburn, 1979 and French, 1996).

In seismic zones, liquefaction may temporarily weaken the lower layer. Other triggering factors include ground loading, riverbank and coastal erosion and plastic deformation of unstable material at depth, e.g. salt.

Metrics and numerical limits

Landscape creep can be regional (tens of square kilometres) or confined to small areas, e.g. due to aspect. Creep rates are slow (0.5 to 15 mm/ year according to Saunders and Young, 1983). In contrast, liquefaction-related movement is rapid, subsiding as post-seismic drainage occurs, but it can also be regional in extent.

An example of a spread in sensitive clays occurred in Sant-Jude, Québec, Canada on May 10th, 2010 where a family of four perished in their house during the rapid mass movement. Its volume was estimated at 520,000 m^3, with a length of 80 m and a width of 275 m. The slope gradient varied between 12° and 20° (Locat et al., 2017). The trigger was thought to be high porewater pressure during spring thaw.

Moreover, 14 historical cases were documented in detail in Québec where the width varied between 145 to 955 m and the distance of retrogression ranged from 75 to 675 m. In sensitive clay spreads, the width is generally larger than the length (Locat et al., 2018).

Key relevant UN conventions and multilateral treaties

Not applicable.

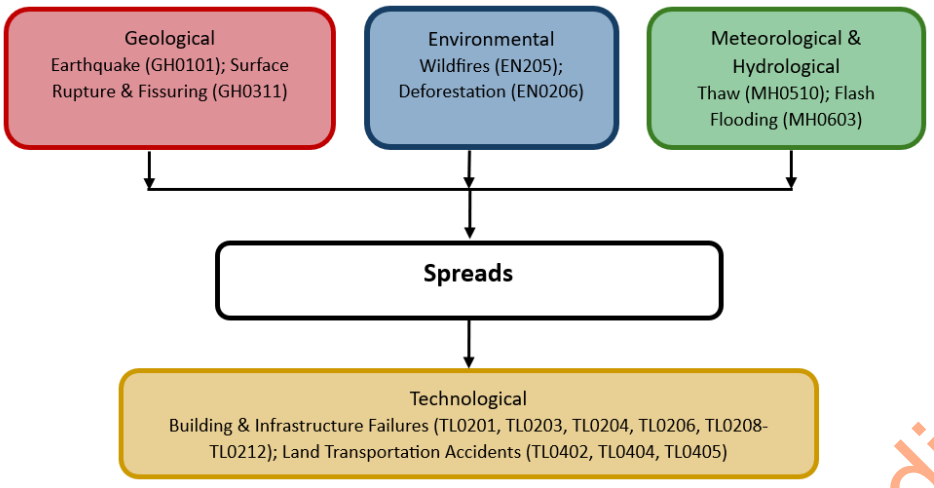
Examples of hazard drivers, impacts and risk management

Hazard Drivers: Ground shaking may induce liquefaction-driven spreading; tectonic uplift can drive cambering, and seasonal changes in rainfall and snowmelt are the typical triggers for landscape creep. In a multi-hazard context, other drivers might include leaking pipes, poor drainage and construction. Spreading landslides can progress to earthflows. Sub-surface groundwater flow tends to be focused and this facilitates piping (subrosion) that can propagate upwards leading to sinkhole formation, e.g. in Ethiopia (Valenta et al., 2021) and cambering and valley bulging, as reported in the UK (Hawkins, 2013).

Impacts: Spreading landslides can rupture infrastructure such as pipelines, cables, buildings, highways and fences and can lead to more significant ground failures such as earth flows.

Multi-hazard Context: The figure below summarises common interactions between spreads and other hazards. However, this information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note also that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

Preliminary – Corrections Pending



Monitoring: The section and the table below offer an overview of monitoring spreads. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Local authorities; Geological Surveys may produce disaster risk data/information
How is the Hazard Observed/Monitored/Forecast?	Spreads can be monitored via satellite imagery, InSAR, and visual observations among others.

Risk Management: The most common mitigation for creep is to ensure proper drainage of water, especially for seasonal creep. Slope modification such as flattening or removing all or part of the landslide mass can be attempted, as well as the construction of retaining walls (Highland and Bobrowsky, 2008).

The Ministère des Transports et Mobilité durable (MTMD, 2024) in the province of Québec has created an interactive website of maps depicting potential zones of slope failures. With most of the population established within the St-Lawrence Lowlands, the region containing sensitive clays, invaluable information has been made accessible to individuals.

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Coordinating agency or organisation

British Geological Survey, Geological Survey of Canada

Preliminary – Corrections Pending

GH0303 / GEOHAZARD / Ground Failure

Debris and earth (mud) flows and rock avalanches

Definition

Flows are gravitational mass movements down a slope in the form of a fluid. Flows often leave behind a distinctive, fan-shaped deposit where the landslide material has stopped moving (cf. British Geological Survey 2024)

Sub-categories of flows may be defined by the type and proportion of material (e.g., soil, debris, or earth and the velocity of the mass movement, cf. Cruden and Varnes, 1996; Hungr et al., 2014). Mudflows are here taken to be a sub-category of earth flows. The term rock avalanche implies extremely rapid, massive, flow-like motion of fragmented rock from a large rock slide or rock fall (Hungr. et al., 2014).

Preliminary – Corrections Pending

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Annotations

Synonyms

Hyperconcentrated flow, Landslide, Mudslide, Mudflow, also termed lahar (see GH0204) if from a volcanic source

Additional scientific description

Debris flows and earth flows usually occur in small, steep stream channels and are commonly mistaken for floods (Highland and Bobrowsky, 2008). The boundary between debris flow and mudflow is gradational with a mudflow consisting of finer sediment (Hungr et al., 2014).

One of the most common types of gravitational mass movements triggered by intense precipitation is a debris flow. It is often called a channelized debris flow as it is triggered in steep mountain stream channels, usually during intense precipitation events, but also during rapid snowmelt. In the media, a debris flow will often be termed a mudslide or mudflow. Another type of debris flow is called a hill slope debris flow, which is also synonymous with debris avalanche (Hungr et al., 2014).

Rock avalanches are a translational form of mass movement where the transported material is dry rock that is fragmented before or during slope failure. They are rapid with long runouts and large volumes and often involve the entrainment of slope material, commonly therefore, giving rise to debris slides or flows. The motion of rock avalanches is massive such that the bulk of the rock fragments move together as a largely coherent mass (Collins, 2014).

Often, there is a gradation of change from slides to flows, depending on the water content, mobility, and evolution of the movement.

Metrics and numerical limits

There is no systematic way of recording debris flows globally but they may exist at the country level. Volume range (10^3–10^6 m^3) for most events (Hungr et al., 2014; Jakob & Hungr, 2005).

Key relevant UN conventions and multilateral treaties

Not identified.

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Flows are generated by precipitation, melting of summit ice or snow from volcanic heat, or glacial outburst floods (Hungr et al., 2014). They can also develop from falls (see GH0301) and rock avalanches, which can evolve into debris flows.

Climate change impacts on permafrost have been associated with increasing incidence of rock avalanche initiation triggered by melting ice or thawing permafrost (USGS, 2018).

Impacts: Rock, debris and earth flows can have devastating impacts. An example of a mudflow is in Indonesia, where on 29 May 2006, hot mud and gas began gushing from a rice field near a gas exploration well in East Java. More than a decade later, the Lusi mudflow continues on the Indonesian island (NASA, 2019). Over the years, flows of boiling mud from the Lusi Mudflow have displaced more than 40,000 people, destroyed 15 villages, and caused nearly USD 3 billion in damage (NASA, 2019). The Lusi eruption has become one of the most dramatic and damaging eruptions of its type. Some villages have been buried by layers of mud 40 metres (130 feet) thick. The mud, which has a consistency similar to porridge, pours constantly from Lusi's main vent. Every thirty minutes or so, surges in the flow send plumes of water vapour, carbon dioxide, and methane shooting tens of meters into the air (NASA, 2019).

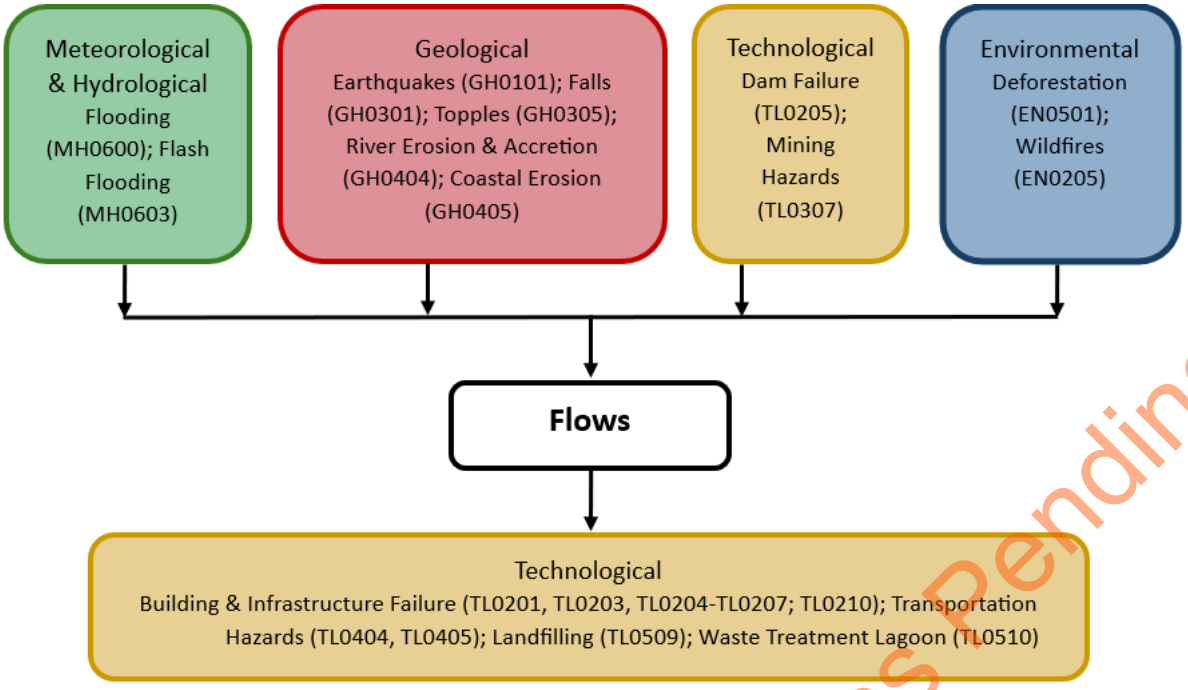
Often referred to as "mudslide" in the media, British Columba Canada, suffered the impacts of an atmospheric river event in November 2021 triggering several debris flows/mudflows and floods as each major road, east of Vancouver was either blocked, destroyed or flooded (Watterodt and Doberstein, 2023). An atmospheric river event is a high-intensity, warm precipitation event originating from the Pacific Ocean. From this event, five people were swept away by a debris flow north of Vancouver and east of Vancouver, two debris flows blocked a highway where more than 275 people were trapped for 48 hours. Major arteries were blocked for about a week; the costs were $675 million (Canadian currency) in insured losses, between $1-5 billion in uninsured losses, and between $900 million to $1.5 billion in estimated economic losses to the supply chain and labour market disruptions (Watterodt and Doberstein, 2023).

Rock avalanches pose some of the most dangerous and expensive geological hazards in mountainous terrain. Typical of these was the Frank Landslide, which occurred on 29 April 1903, and involved 110 million tonnes (~44 million cubic meters) of limestone released from the summit of Turtle Mountain, Alberta. The rock mass that fell was 150 m deep, 425 m high and 1 km wide (Frank Slide Interpretive Centre, 2018). The Frank Landslide occurred at night. It was triggered by unusual weather conditions (repeated freeze-thaw cycles) influenced also by subsurface mining. The rock avalanche buried part of the town of Frank killing at least 80 people in its path; it is Canada's deadliest landslide event (Frank Slide Interpretive Centre, 2018).

In July of 2021, the town of Lytton, BC, Canada recorded the hottest place on earth (~49.9°C) for a few days. Soon after, it was ravaged by forest fires. The following month in August, debris flows triggered during heavy rains in steep stream channels contributed to the devastation in and around Lytton.

Multi-hazard Context: The figure below summarises common interactions between flows and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

Preliminary – Corrections Pending



Monitoring: The section and the table below offer an overview of monitoring flows. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Local authorities; Geological Surveys may produce disaster risk data/information
How is the Hazard Observed/Monitored/Forecast?	Slopes that may generate flows can be monitored via satellite imagery, InSAR, and visual observations, among others. Other techniques include threshold-based rainfall warning systems.

Risk Management: Instrumental monitoring to detect movement and the rate of movement can be implemented, for example, extensometers, global positioning system (GPS), seismometers, aerial photography, satellite images, LiDAR (Highland and Bobrowsky, 2008) with varying degrees of success.

Mitigation actions include active protections to remove the hazard itself and passive protections, which seek to mitigate the impacts (e.g. on buildings and communication routes) (Dennis and Didier, 2024).

- A*ctive protections* can include (i) general methods, such as surface or deep drainage, and slope vegetation that limits erosion due to runoff (gully excavation) and infiltration that alters mechanical properties (friction, cohesion of rock joints); (ii) supports, such as retaining walls, rock bolts or anchored mesh covered with sprayed concrete; (iii) wire mesh (draped or pinned), i.e., metal structures designed to contain the massif and prevent the spread of falling rocks and blocks that could evolve into a flow; and (iv) scaling/mining, which are radical solutions that comprise removing unstable elements, although these solutions are not always as definitive as expected (the continuous alteration and the blast vibrations are often harmful to the stability of the surrounding massifs) (Dennis and Didier, 2024). Along the highway to Whistler BC, mitigation against debris flows was made with building catchment basins (Blais-Stevens and Hungr., 2008).

Preliminary – Corrections Pending

Mitigation measures: left: shooting channel; right; debris basin/catchment basin (Blais-Stevens and Hungr., 2008)

- *Passive protections* include barriers, diverters, fences etc. that either divert, block or inhibit the flows. These are placed according to numerical simulation of flow hazard, and their use is dependent on the slope material. (i) barriers and dikes placed at the foot of unstable slopes to stop the propagation of rock elements before reaching infrastructure or other exposed assets; (ii) diverters or embankments can be installed on the slope to divert the flow towards a space without assets; (iii) protection galleries, similar to avalanche tunnels, are likely to protect communication routes when crossing corridors; (iv) rigid fences can be placed on steep slopes as close as possible to the starting areas; however, their installation is often difficult to achieve; and (v) deformable wire-mesh can be placed lower on the slopes until they are close to the issues at stake; the most well-known case is the use of 'submarine' type nets (used during the Second World War to prevent the penetration of ports by submarine vehicles) stretched between rigid poles and maintained by fusible carabiners; this device is thus calculated to resist an impact energy previously determined in the study of randomness and its propagation (Dennis and Didier, 2024).

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Preliminary – Corrections Pending

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Coordinating agency or organisation

British Geological Survey / Geological Survey of Canada

Preliminary – Corrections Pending

GH0304 / GEOLOGICAL / Ground Failure

Rock, debris and earth (mud) slide

Definition

A slide is a movement of a mass of rock, debris or earth on an individualised failure surface (adapted from Dennis and Didier, 2019).

Sub-categories of slides may be defined by the type of material (e.g., rock, soil, debris, or earth) and the velocity of the mass movement (cf. Cruden and Varnes, 1996; Hungr et al., 2014). Mudslides are here taken to be a sub-category of earth slides.

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Annotations

Synonyms

Translational slide, Rotational slide

Additional scientific description

Different types of slides can be distinguished according to the shape of the failure surface. These can be identified as translational slides and rotational slides:

- *Translational slides* generally occur on one or two planes (referred to as 'wedges') of pre-existing discontinuity(s) in the rock mass. A well-known example in France is the Claps de Luc-en-Diois where, in 1442, thick limestone beds slipped on a stratification plane following the erosion of the foot of the slope by the Drôme River. The volume of the slip exceeded 1 hm^3. But the largest rock slide in the Alps in the last two millennia was the one that affected the marl slope north of Mont Granier in November 1248. Nearly 500 hm3 of marl rock slid eastward on the stratification joints, destroying several villages and killing more than 1000 people (Dennis and Didier, 2019).
- *Rotational slides* occur on an axis-symmetric surface; they are sometimes called circular slides because, on a vertical section, the failure surface is an arc of a circle. They can occur in continuous massifs (often in soils) or without discontinuity planes allowing translational sliding. An example is given by the slide from La Clapière to Saint-Etienne-de-Tinée in France, with a volume of about 50 hm3 (Dennis and Didier, 2019).

Metrics and numerical limits

Not identified.

Key relevant UN conventions and multilateral treaties

Not applicable.

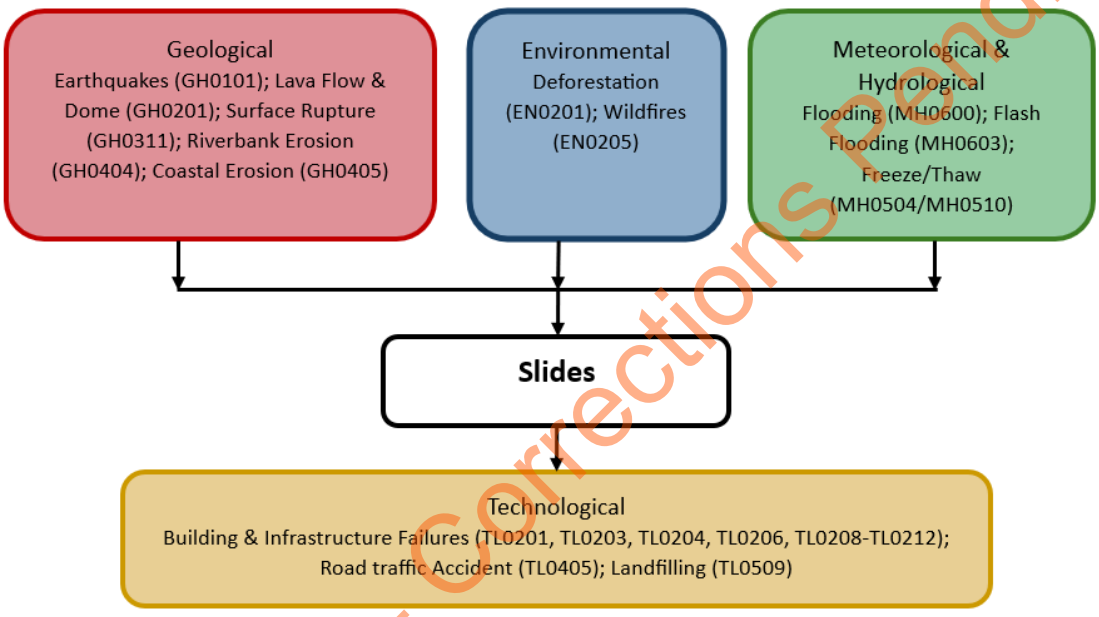
Preliminary – Corrections Pending

Examples of hazard drivers, impacts and risk management

Hazard Drivers: High precipitation, natural erosion, temperature variations or extreme stresses such as earthquakes can trigger rock slides and rock falls.

Impacts: Six of the 26 catastrophic landslides of the 20th Century listed by the United States Geological Survey (2018) were associated with rock slides, including the Usoy rock slide, USSR (1911); Khait rock slide, USSR (1949, 12,000 to 20000 deaths); and the Bairaman rock slide debris avalanche, Papua New Guinea (1986, village destroyed). These three rock slides were triggered by earthquakes. In 1974 in Peru, the Mayunmarca rock slide-debris avalanche, which resulted in the loss of 450 lives was associated with high rainfall.

Multi-hazard Context: The figure below summarises common interactions between earthquakes and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Preliminary – Corrections Pending

Monitoring: The section and the table below offer an overview of landslide monitoring. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Local Authorities; Geological Surveys can produce disaster risk data / information
How is the Hazard Observed/Monitored/ Forecast?	Slides can be monitored via satellite imagery, InSAR, and visual observations, among others.

Risk Management: In terms of natural hazards, the Encyclopaedia of the Environment reported two categories of protection: active protections to remove the hazard itself and passive protections, which do not seek to oppose natural phenomena only to limit their harmful consequences for developments (buildings, communication routes) (Dennis and Didier, 2019).

- A*ctive protections* are diverse and include (i) general methods, such as surface or deep drainage, and slope vegetation that limits erosion due to runoff (gully excavation) and infiltration that alters mechanical properties (friction, cohesion of rock joints); (ii) supports, such as retaining walls, rock bolts or anchored mesh covered with sprayed concrete; (iii) wire mesh (draped or pinned), i.e., metal structures designed to contain the massif and prevent the spread of falling rocks and blocks; and (iv) scaling/mining, which are radical solutions that comprise removing unstable elements, although these solutions are not always as definitive as expected (the continuous alteration and the blast vibrations are often harmful to the stability of the surrounding massifs) (Dennis and Didier, 2019).
- *Passive protections* are also diverse: (i) barriers and dikes are gabions or concrete blocks placed at the foot of unstable slopes; their purpose is to stop the propagation of rock elements before reaching the stakes; their location, which requires sufficient space and their dimensioning, takes into account the properties of the materials that constitute them, but first of all numerical simulations that are made to model the propagation of blocks (trajectory circulations); (ii) the diverters are also embankments; installed on the slope, they divert the flow of the elements towards a space without stakes; (iii) protection galleries, similar to avalanche tunnels, are likely to protect communication routes when crossing corridors; (iv) rigid fences are placed on steep slopes as close as possible to the starting areas; their installation is often difficult to achieve; and (v)

deformable wire-mesh can be placed lower on the slopes until they are close to the issues at stake; the most well-known case is the use of 'submarine' type nets (used during the Second World War to prevent the penetration of ports by submarine vehicles) stretched between rigid poles and maintained by fusible carabiners; this device is thus calculated to resist an impact energy previously determined in the study of randomness and its propagation (Dennis and Didier, 2019).

The appropriate responses to reduce the risks associated with rock instabilities are effective but often require a large budget. It is not viable to consider eliminating risk wherever it exists. The best protection is always based first on geological reconnaissance, followed by preventative actions such as drainage or regular purging of unstable elements and on monitoring based on measurements when movements are detected. Such monitoring often triggers an alert with a road closure or evacuation of an inhabited area (Dennis and Didier, 2019).

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Coordinating agency or organisation

British Geological Survey, Geological Survey of Canada

Preliminary – Corrections Pending

GH0305 / GEOLOGICAL / Ground Failure

Rock, debris and earth topples

Definition

A topple is the forward rotation out of the slope of a mass of soil or rock about a point or axis below the centre of gravity of the displaced mass (Cruden and Varnes, 1996).

Sub-categories of topples may be defined by the type of material (e.g., rock, soil, debris, or earth, modes of toppling (Goodman and Bray, 1976) and the velocity of the mass movement (cf. Cruden and Varnes, 1996; Hungr et al., 2014).

References

Cruden, D.M., Varnes, D.J.,1996, Landslide Types and Processes, Transportation Research Board, U.S. National Academy of Sciences, Special Report, 247: 36-75

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Hungr, O., S. Leroueil and L. Picarelli, 2014. The Varnes classification of landslide types, an update. Landslides, 11:167-194.

Annotations

Synonyms

Not applicable.

Additional scientific description

Topples may lead to falls or slides of the displaced mass depending on the geometry of the moving mass, the geometry of the surface of separation, and the orientation and extent of the kinematically active discontinuities.

Goodman and Bray (1976) describe several modes of toppling (further discussed by Hungr et al. 2014):

- Flexural topples – occur in rocks with one preferred discontinuity system, oriented to present a rock slope with semi-continuous cantilever beams.
- Block topples – occur where the individual columns are divided by widely-spaced joints.
- Chevron topples – occur where the dips of toppled beds are constant and the change of dip is concentrated at the surface of rupture.
- Block-flexure topples – are characterized by 'pseudo-continuous flexure of long columns through accumulated motions along numerous cross joints'.

Metrics and numerical limits

Topples range from extremely slow to extremely rapid, sometimes accelerating throughout the movement (Cruden and Varnes, 1996).

Key relevant UN conventions and multilateral treaties

Not applicable.

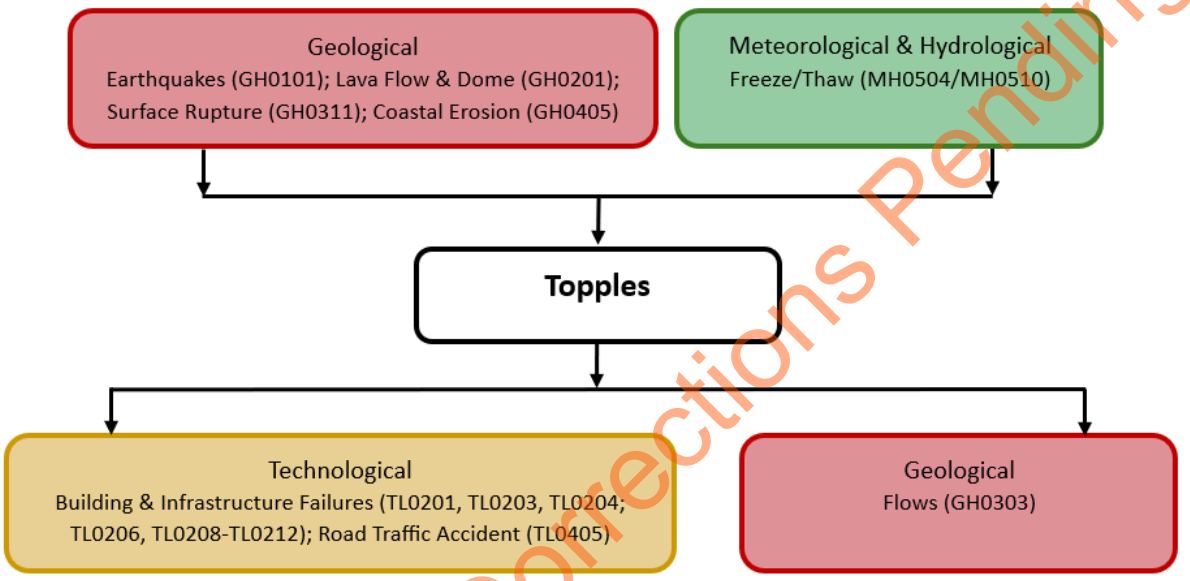
Preliminary – Corrections Pending

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Toppling is sometimes driven by gravity exerted by material upslope of the displaced mass, and sometimes by water or ice in cracks in the mass, or thermal expansion and vibration.

Impacts: Topples can be life-threatening. Topples can damage property beneath the fall line of large rocks. A topple often results in the formation of debris or a debris cone at the base of the slope; this pile is called a talus cone. New talus cones do not have any plants growing on them. Old talus cone can have weeds and even trees on them.

Multi-hazard Context: The figure below summarises common interactions between topples and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring topples. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Local Authorities; Geological Surveys may produce disaster risk data/information
How is the Hazard Observed/Monitored/ Forecast?	Slopes or cliffs that topples may occur on can be monitored via satellite imagery, InSAR, and visual observations, among others.

Risk Management: Mitigation measures for rock, debris and earth topples are similar to those for rockfalls and include rock curtains or other slope covers, protective covers over roadways, retaining walls to prevent rolling or bouncing, explosive blasting of hazardous target areas to remove the source (scaling), removal of rocks or other materials from highways and railroads can be used to minimise risk (Sassa et al., 2018).

Rock bolts or other similar types of anchoring used to stabilise cliffs, as well as scaling, can lessen the hazard. Warning signs are recommended in hazardous areas for awareness. Stopping or parking under hazardous cliffs should be warned against (Highland and Bobrowsky, 2008).

Preliminary — Corrections Pending

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Coordinating agency or organisation

British Geological Survey, Geological Survey of Canada

Preliminary – Corrections Pending

GH0306 / GEOLOGICAL / Ground Failure

Submarine Gravitational Mass Movement ('Landslide')

Definition

A submarine gravitational mass movement ('Landslide') is the downslope movement of sediment or rock due to gravity, occurring when the downslope forces exceed the sediment's resistance to movement (Adapted from Lee et al., 2007).

Reference

Lee, H.J., J. Locat, P. Desgagnés, J,.D. Parsons, B.G. McAdoo, D.L. Orange, P. Puig, F. Wong, P. Dartnell and E. Boulanger, 2007. Submarine mass movements on continental margins. In: Continental Margin Sedimentation. pp. 213-274. Wiley.

Preliminary – Corrections Pending

Annotations

Synonyms

Mass movement, Mass flow, Gravity flow, Slump, Mudflow, Debris flow, Liquefaction flow, Turbidity current.

Additional scientific description

Submarine gravitational mass movements ('Landslides') commonly occur in fjords, submarine canyons, active river deltas, volcanic islands, and open continental slopes. Evaluating the stability of seabed sediment requires understanding the driving stresses and sediment strength. Driving stresses include gravity, earthquakes, and storm waves. Resisting strength is reduced by pore water and gas pressures, groundwater seepage, rapid sediment deposition, cyclic loading, and human activity. Once slopes have become unstable or have failed, sediment strength may continue to decrease so, following slope failure, the failed mass moves downslope under the influence of gravity.

Submarine gravitational mass movements are classified as mass sediment movements. These include slides (translational and rotational slumps) and mass flows (mudflow, debris flow, liquefaction and turbidity current). If the moving sediment is a viscous fluid, this is termed a mass flow (gravity flow). If the movements are essentially rigid, internally undeformed masses along discrete slip planes, they are termed slides. The movement formed by 'blocks' of failed material rotating along curved slips are called slumps. Movements on a planar surface are termed translational slides. In both types, movement can be fast or slow. Extremely slow movement is called creep (see GH0302). Submarine slides can become mass flows (gravity flows) as the failed mass progressively disintegrates and continuous downslope movement occurs. End members of disintegrating slides have different terms. Debris flows are where the sediment is heterogeneous and may include larger clasts supported by a matrix of fine sediment. Mud flows are predominantly muddy sediment. Turbidity currents involve the downslope transport of a relatively dilute suspension of sediment grains that are supported by an upward component of fluid turbulence. Recent submarine landslide research has: (i) shown that landslides and sediment waves may generate similar deposits, which require careful interpretation; (ii) expanded knowledge of how strength develops in marine sediment; (iii) improved techniques for predicting sediment rheology; and (iv) developed methodologies for mapping and predicting the medium- to large-scale regional occurrence of submarine landslides.

Most submarine gravitational mass movements have multiple causes, which differ significantly from their subaerial counterparts. For example, the gradient of a seabed slope is not always a determining factor, as some of the largest submarine landslides occur on the shallowest slopes. Submarine gravitational mass movements are triggered by an increase in driving stresses, a decrease in sediment strength, or a combination of the two. These triggers include erosion, rapid sedimentation on delta fronts and earthquakes. Erosion is common in deep-sea channels, submarine canyons and other active sediment-transport systems. When seabed surfaces are undercut, this can decrease the stability by increasing shear stress and/or decreasing the shear

strength. With earthquakes, the earthquake-induced shear stresses are large relative to sediment shear strength because the earthquake must accelerate all the sediment columns including the interstitial water. The sediment shear strength is lowered because it builds up in proportion to the submerged unit weight of the sediment and may be even lower if there are excess pore pressures. The ratio of driving stress to resisting strength is high relative to that on land. Rapid sediment accumulation contributes to failure because most of the weight of newly added sediment is carried by pore-water pressures and the shear stress acting downslope increases more rapidly. The shear stress may also increase because more sediment may be deposited at the head of the sloping surface than at the toe, exceeding the critical slope angle of sediment. In addition, the following may result in failure: retarded sediment shear strength development, increased development of shear stress because of the thickness of the sediment body, and increased development of shear stress because of increases in the slope steepness.

Metrics and numerical limits

Submarine gravitational sediment movement has been recorded during two events where submarine telephone cables were broken. The velocities recorded were up to 28 m/s (101 km/h) during the 1929 Grand Banks event and 5 to 16 m/s (18-57 km/h) in the Strait of Luzon between Taiwan and the Philippines from 2006 to 2015. (Løvholt, et al., 2018)

Key relevant UN conventions and multilateral treaties

Not found

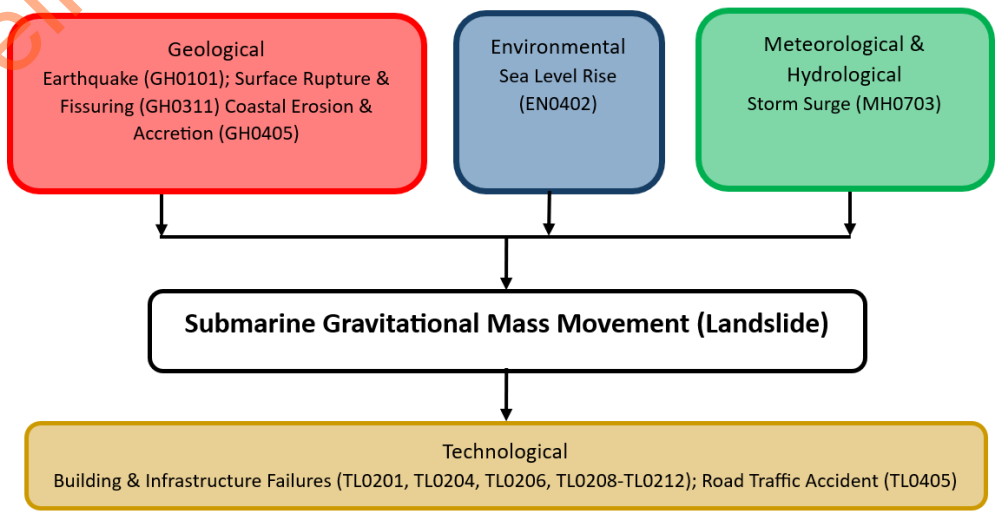
Examples of hazard drivers, impacts and risk management

Hazard Drivers: The drivers of submarine gravitational mass movements include gravity, earthquakes and storm waves. They can be triggered by ground shaking (see GH0101) from earthquakes and volcanic activity, for example on volcanic islands, or submarine volcanoes.

Impacts: In coastal and offshore regions, submarine gravitational mass movements threaten installations including oil platforms, pipelines, cables, and wind turbines. Mass submarine sediment failures are also one of the most important sources of sedimentation from shallow to deep-water environments and of shaping continental margins (McAdoo et al., 2000). Hence, a better understanding of submarine gravitational mass movements is of great importance in the development of offshore resources exploration and protection, sustainable flood risk management, hazard assessments for engineering and environmental projects, and also in hydrocarbon reservoir management (McAdoo and Watts, 2004; Masson et al., 2006).

Understanding submarine gravitational mass movements has primarily focused on their role in generating tsunamis. For example, in 1969, an oil platform in the Gulf of Mexico collapsed when the soft seabed was destabilised during a hurricane. The most important historical event with significant loss of life was in 1998 in Papua New Guinea when a slump-generated tsunami killed over 2200 people on the nearby coast. Other important events include the 1929 Grand Banks (M7.2) earthquake-induced landslide tsunami in which 28 people died, and in 1964 during the Great Alaska earthquake, when submarine gravitational mass movements in Resurrection Bay and Port Valdez caused tsunamis that killed 45 people (Parsons et al., 2014). An additional risk is posed to submarine telegraph and fibre optic cables. For example, in 1929 the Grand Banks gravitational mass movement broke trans-Atlantic telegraph cables off Newfoundland.

Multi-hazard Context: The figure below summarises common interactions between submarine gravitational mass movements and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Preliminary – Corrections Pending

Monitoring: Not Applicable

Risk Management: Not Applicable

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Coordinating agency or organisation

British Geological Survey.

Preliminary – Corrections Pending

GH0307 / GEOHAZARD / Ground Failure

Liquefaction

Definition

Liquefaction refers to the loss of strength experienced in loosely packed, saturated or close to saturated sediments at or near the ground surface in response to strong ground shaking, such as earthquakes, cyclic loading (repeated application of stresses), and vibration from machinery, or due to the development of excess pore water pressure resulting from a change in head or confining pressures. (c. AGI, 2017; USGS, no date).

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Preliminary – Corrections Pending

Annotations

Synonyms

Quicksand, Running sand, Boiling sand.

Additional scientific description

For liquefaction to occur, the shear strength of the soil volume (e.g., the strength due to contact between individual soil grains) must be reduced to near zero. Soil compression increases the pore-water pressure, causing the water to move toward the Earth's surface where pressure is lower. Under typical loading (e.g., from temperature changes, increased groundwater), the water then drains and contact between grains retains their strength. However, when loading cycles occur rapidly, such as during ground shaking, intermittent drainage is prohibited, and liquefaction may initiate (Kramer, 1996). During heavy precipitation, rapid snowmelt, and earthquakes, sensitive glaciomarine clays can lose strength and liquefy. The salts holding the clay-sized particles are leached triggering liquefaction (e.g. Crawford, 1968).

The following characteristics are common to deposits most susceptible to liquefaction (Kramer, 1996):

- Loose, sandy soils; however, liquefaction has been observed in gravels and coarse silts (Seed et al., 2003)
- Rounded, well-sorted grains (e.g., uniform grain size); these compact most easily
- Recently deposited, especially of Holocene age (<11.7 ky), uncompacted soils including human-made deposits
- Soils that are saturated, below sea level, or within a few meters of groundwater.

Some of the most common landforms in which liquefaction occurs are marshlands, riverbanks, beaches, and floodplains. Structureless anthropogenic soils, such as those placed during land reclamation are susceptible to liquefaction.

During construction, liquefaction occurs when the groundwater conditions reduce the effective stress of the soil to zero. At this point, the seepage pressure can disturb the soil structure and mobilise the sediment as quick, running or boiling sand (BRANZ Seismic Resilience, no date). Post-earthquake field studies have shown that earthquake-triggered liquefaction often recurs at the same locations (Kramer, 1996).

In general, sites closer to an earthquake's epicentre are more likely to liquefy, while the distance at which sites are susceptible to liquefaction increases with moment magnitude (MW) and the duration (or number of cycles) of ground motion.

Metrics and numerical limits

Liquefaction susceptibility can be assessed in advance of earthquakes (e.g., Lirer at al., 2019). Often, this is based on a simplified indication of a site's likelihood to liquefy. A common approach is the liquefaction potential index (LPI), which considers a factor of safety against liquefaction, the layers of earth that might liquefy, and the proximity of these layers to the ground surface (Iwasaki et al., 1984). While several methods are available for determining the factor of safety, they generally reflect the ability of the soil to resist the power of an earthquake. Soil resistance is either measured in situ or estimated based on the surficial deposits and hydrological conditions (Kramer, 1996; Witter et al., 2006). The comparison to earthquake power can be deterministic for the worst-case scenario earthquake (Orhan et al., 2013), or probabilistic for the range of possible earthquakes that could occur (Witter et al., 2006).

Liquefaction susceptibility maps (also called liquefaction hazard maps) are currently not available on a global scale but are often provided by the geological agencies in a region. See USGS (no date) for an example of a liquefaction map for the San Francisco Bay Area.

The smallest earthquake for which liquefaction records exist was MW ~ 5, with the most distant observed liquefaction reaching only ~2 km; by contrast, the most distant liquefaction for an earthquake of MW >7 may exceed 100 km (Ambraseys, 1988). During the 2011 MW 9.0 Tohoku earthquake, damage due to liquefaction occurred at least 250 km from the epicentre (Yamaguchi et al., 2012).

Key relevant UN conventions and multilateral treaties

Not identified.

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Drivers of liquefaction are related to soil properties such as particle shape, grading, uniformity of grain size and relative density or voids ratio. Soil saturation can also influence liquefaction. Liquefaction can be triggered by rapid drawdown from erosion at the base of a slope. Liquefaction can also be triggered by intense rainfall (Najar et al., 2023) and earthquakes. Loading can also trigger liquefaction.

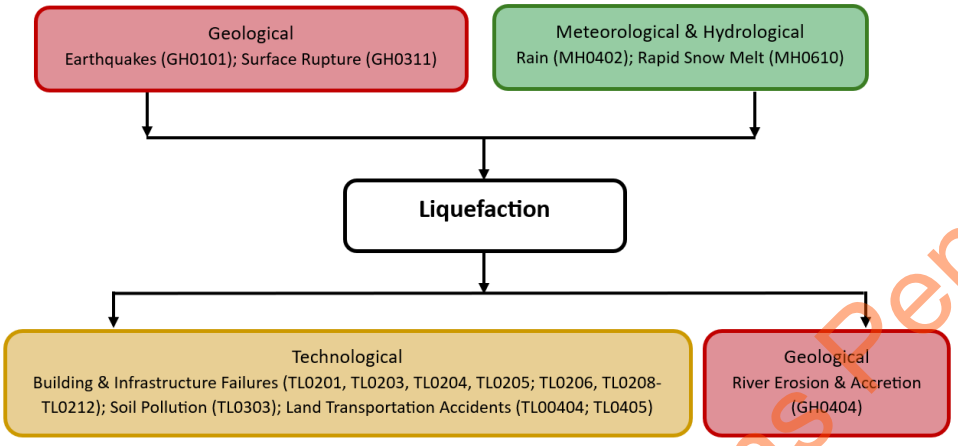
Impacts: The consequences to structures and infrastructure of liquefaction include: differential settlement of structures often resulting in cracking; loss of bearing support; flotation of buried structures such as sewer lines, tanks, and pipes; strong lateral forces against retaining structures such as seawalls; lateral spreading (limited lateral movement); and lateral flows (extensive lateral movement), particularly impacting on slopes or valley sides (e.g., Cubrinovski, 2013).

Earthquake-induced liquefaction can have varied effects on the surrounding built environment. Buildings, infrastructure, and utilities normally supported by the soil may sink, or undergo cracking or other structural damage; pile foundations may buckle or tilt; and lightweight, buried masses such as pipelines may become buoyant and float to the surface. Liquefaction can also cause rapid settling of sediments, flooding (including breaches of earthen embankments or other retaining structures), and lateral spreading of soils (Kramer, 1996).

Liquefaction associated with the Christchurch earthquakes caused significant disruption to transport infrastructure, and to storm- and wastewater networks, and posed physical and mental health hazards for the exposed community and clean-up (Villemure et al., 2012; Cubrinovski, M., 2013.). From a human health perspective, the liquefaction material posed several hazards. Due to the extensive damage to the sewage disposal networks from lateral spreading and differential settlement, there was a risk that much of the liquefaction ejecta had been contaminated with raw sewage creating a long-term health risk to the population. During hot and windy conditions, the dry finer portions of silt were mobilised by the wind creating a possible respiratory health hazard. Many volunteers were involved in the clean-up operations. Indeed, the much-celebrated Student-Army was successfully used to coordinate the work around the city (Villemure et al., 2012).

Preliminary – Corrections Pending

Multi-hazard Context: The figure below summarises common interactions between liquefaction and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring liquefaction. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Earthquake early warning (EEW) systems can indirectly inform about liquefaction hazards. EEW systems trigger warnings of an earthquake in regions remote to the source and are maintained by the national organizations with the remit to monitor seismic activity (e.g., USGS for the United States). In some countries, some local/urban systems also exist that are maintained by the local government.
How is the Hazard Observed/Monitored/Forecast?	Not Applicable

Risk Management: The primary mitigation measure is to use planning to avoid development over liquefiable soils. These include in-situ testing of liquefaction resistance using standard penetration tests, cone penetration tests, shear wave velocity recordings, and dilatometer tests (Kramer, 1996); land micro zonation via LPI or another assessment parameter that prohibits building on susceptible deposits (Lirer et al., 2019). Soil stabilization can be carried out via compaction methods or injection of grout, such as vibrostone columns and dynamic compaction (Shenthan et al., 2004). Other types of mitigation are incorporated in building design (NZGS and MB IE, 2017). During construction, controlling both the rate of excavation and the head, or increasing seepage flow paths to reduce seepage forces are the key methods used to minimise liquefaction (Pane et al., 2015). Nature-based solutions can be used to stabilise soil, such as vegetation for stabilising soils in coastal areas (e.g., Kumar et al., 2021).

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Preliminary – Corrections Pending

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Coordinating agency or organisation

British Geological Survey, Geological Survey of Canada

Preliminary – Corrections Pending

GH0308 / GEOLOGICAL / Ground Failure

Sinkhole

Definition

Sinkholes (also known as dolines) are depressions or holes in the ground caused by the dissolution, collapse or erosion of rock below the land surface. This is one of several hazards that result in subsidence, i.e., lowering or collapse of the ground (adapted from USGS, no date; and BGS, no date).

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Annotations

Synonyms

Doline cenote, Sink, Sink-hole, Swallet, Swallow.

Additional scientific description

Dolines (sinkholes) are part of the hydrological system that shapes karst landscapes (landscapes resulting from the dissolution of soluble rocks such as chalk, gypsum or limestone). They can be considered in terms of fluid recharge, through-flow and discharge (e.g., springs and discharge points). Their rates of formation reflect the lithological and hydrological conditions (head and discharge).

Groundwater chemistry is important in influencing the rate and distribution of sinkholes. For example, while limestone is only very weakly soluble in water of neutral pH, its solubility increases in acidic conditions, such as due to the input of carbon dioxide from biological transpiration or due to the oxidation of pyrite. Commonly, the mixing of water from different flow paths results in increased dissolution potential. Dissolution may result from both meteoric recharge and groundwater or hypogene fluid flow (water or other fluids and gases) (Dublyansky, 2014).

Sinkholes are classified in accordance with the mode of formation, including but not limited to the following (e.g., Waltham et al., 2004):

- dissolution sinkhole is formed by dissolutional lowering of the exposed soluble rock surface in and around zones of water recharge to soluble rock;
- a subsidence sinkhole results from recharge water mobilisation of sediment into underlying cavernous rock;
- a suffosion sinkhole is formed due to recharge water mobilisation of sediment through unconsolidated sediment cover over karst;
- a collapse sinkhole results from the collapse of insoluble capping rock into underlying cavernous rock;

Preliminary – Corrections Pending

- a buried sinkhole is sediment filled;
- a drop out sinkhole is formed rapidly due to soil cover collapse.

The triggering of sinkholes can also be the result of either surface or subsurface changes in load or groundwater conditions. Although a natural process, the formation of sinkholes is often accelerated or triggered by human action, for example, collapse subsidence associated with mining Sinkholes can also occur in specific non-soluble rock settings such as lava tubes or pseudokarst.

Other types of karst hollow (EPA, 2002) with internal drainage include karst geomorphological features referred to as uvala (a closed depression with multiple recharge points), polje (a closed depression with a wide flat-floored and long axis developed parallel to major structural trends), cockpit (a star-shaped depression with a concave floor and surrounded by steep convex hill slopes) and structurally guided pipes.

Many new sinkholes have been correlated to land-use practices, especially from groundwater pumping and construction and development practices. Sinkholes can also form when natural water drainage patterns are changed, and new water-diversion systems are developed. Some form when the land surface is changed, such as when industrial and runoff-storage ponds are created. The substantial weight of the new material can trigger an underground collapse of supporting material, causing a sinkhole (USGS, 2018).

The overburdened sediments that cover buried cavities in some aquifer systems are delicately balanced by groundwater fluid pressure, whereby the water below ground is actually helping to keep the surface soil in place. Groundwater pumping for urban water supply and for irrigation can produce new sinkholes in sinkhole-prone areas. If pumping results in a lowering of ground-water levels, then underground structural failure, and thus, sinkholes can occur (USGS, 2018).

Broken land drains, water mains and sewerage pipes, increased rainfall, storm events, modified drainage and diverted surface water can all help wash sediment into the underlying soluble rock, causing subsidence. There have been many well-documented occurrences of sinkholes forming beneath broken water mains, unlined stormwater culverts and leaking swimming pools (BGS, 2024). In some locations, dissolution is driven by the upward movement of groundwater

Metrics and numerical limits

Currently, there is no systematic reporting of global sinkholes and their impacts. The size and density of sinkholes reflect the distribution of recharge or flow paths, for example, surface karst with numerous small recharge points (diffuse flow) over heavily fractured, more permeable rock, or fewer large recharge points in lower permeability strata. Similarly, where groundwater flow dominates, sinkhole formation processes are focused on structural and lithological boundaries. The size of sinkholes ranges from a few centimetres to hundreds of metres in diameter, and depths of decametres to a hundred metres or more.

Key relevant UN conventions and multilateral treaties

Not identified.

Examples of hazard drivers, impacts and risk management

Hazard Drivers: The formation of sinkholes can be influenced by heavy or prolonged rainfall, changing groundwater levels (natural and anthropogenic), inundation (e.g., flooding or pipe leakage), loading (e.g., flooding or construction), erosion, and weathering and ground vibration. Sinkholes can also form as a result of sub-surface activity such as mining or tunnelling. In many landscapes, sinkholes form imperceptibly slowly (USGS, 2018; BGS, 2024).

Impacts: Collapse subsidence can be rapid. This is particularly significant in urban landscapes where the surface rupture can damage buildings and infrastructure, occasionally associated with loss of life (Waltham et al., 2004). For example, sinkholes in Guatemala City in 2007 and 2010 damaged roads, and buildings and resulted in loss of life (Hermosilla, 2012).

Multi-hazard Context: The figure below summarises common interactions between earthquakes and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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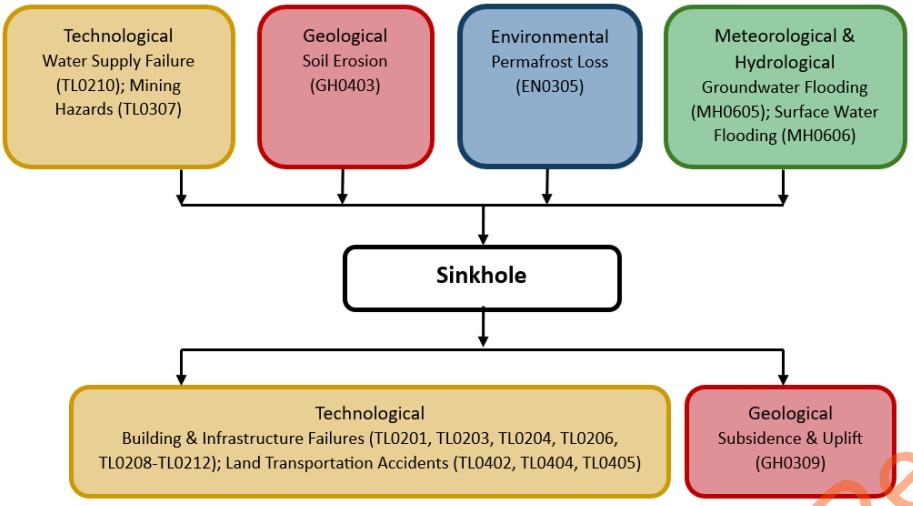

Monitoring: No Information Available

Risk Management: The best form of control is avoidance through planning: various remote sensing, geophysical and intrusive ground investigation techniques can be applied to locating sinkholes to enable the design of construction methods, for example, transferring load to more competent strata with piles, or the incorporation of span distances for rafts or geotextiles (Waltham et al., 2004). Some construction techniques focus on void filling, for example, types of grouting are used to prevent or remediate sinkholes (Waltham et al., 2004).

Any remediation solution should fully consider the hydrological and hydrogeological context.

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Coordinating agency or organisation

British Geological Survey.

Preliminary – Corrections Pending

GH0309 / GEOLOGICAL / Ground Failure

Subsidence and Uplift

Definition

Subsidence is a lowering or collapse of the ground (BGS, 2020). Uplift is the converse.

References

BGS, 2020. Subsidence and shrinking and swelling soils. British Geological Survey (BGS). www.bgs.ac.uk/geology-projects/shallow-geohazards/clay-shrink-swell Accessed 11 October 2024.

Annotations

Synonyms

Uplift, Subsidence, Ground deformation, Surface faulting, Coseismic subsidence, Coseismic uplift, Volcanic subsidence, Volcanic uplift

Additional scientific description

Subsidence and uplift can be localised and associated with near-surface, relatively shallow crustal, or human-generated processes such as mining or tunnelling, consolidation, permafrost loss (permafrost thaw - HIP EN0305), sinkholes, karst collapse, groundwater fluctuations and moisture changes on expansive soils (BGS, 2020). Several crustal-scale processes drive subsidence and uplift that tend to be regional or global in scale. Crustal movements occur in response to several different mechanisms, including tectonics, changes to surface loading caused by glacier and ice sheet changes (glacial isostatic adjustment), sediment transport (erosion and accretion), water loading (hydro-isostatic adjustment) and mantle flow (upwelling and downwelling). These operate over different temporal and spatial scales. Tectonic uplift and subsidence are the distributed persistent vertical ground deformations (warping) that result from displacement on a dipping (inclined) fault (Styron, 2019). Earthquake surface ruptures and fissures are localized ground displacements that develop during and immediately after an earthquake, where the fault which hosted the earthquake intersects the Earth's surface. Surface ruptures represent the upward continuation of fault slip at depth, while fissures are smaller displacements, or more distributed deformation in and around the rupture area (PNSN, no date).

Ground-level rise is commonly associated with plate convergence, such as the Himalayas where the Eurasian and Indian plates converge (USGS, 2015). Subsidence can also be associated with plates moving apart, for example the Ethiopian Rift Valley. The relative motion of the crust on either side of faulting associated with earthquakes results in persistent or permanent deformation of the Earth's surface. Surface ruptures, fissures, and uplift and subsidence are all manifestations of this longer-term deformation, and although less dramatic, may all pose hazards during and after earthquakes.

Volcanic uplift and subsidence are deformations of the ground associated with volcanic unrest and eruptions (Dzurisin, 2007). During unrest at volcanoes, ground deformation is usually on the order of millimetres to centimetres per year and it is not uncommon for the centre of uplift to move (Di Vito et al., 2016). Some caldera volcanoes may show deformation rates of metres per year and some calderas show very long-term ground deformation ('resurgence') which may cause uplift of up to 1 km over hundreds to thousands of years (Acocella, 2019). The Campi Flegrei caldera (Italy) is 12 km across and lies under the outskirts of Naples. At least 5 m of uplift was observed in the hours to days before the last eruption at Campi Flegrei in 1538 (from Monte Nuovo) resulting in the seaward retreat of the shoreline (Acocella, 2019 and references therein). Campi Flegrei experienced major uplifts in 1950-1951, 1969-1972 and 1982-1984 which cumulatively raised the town of Pozzuoli by 4 m. Pozzuoli experienced a maximum of 1.8 m of uplift during unrest in 1982-1984 (Acocella, 2019 and references therein).

Preliminary – Corrections Pending

Erosional/depositional-isostatic deformation occurs in response to the stress changes induced by changing sediment load (erosion/deposition). Changes to terrestrial water loads may have anthropogenic or climatic drivers and may be seasonal. Changes to ocean water heights and the resulting crustal response have a long-term component related to global glacial isostatic adjustment, as well as important seasonal and climate cycles (e.g., El Nino/Southern Oscillation) contributions.

In the marine coastal environment, sediment transport and global sea-level fluctuations drive shoreline change. Sediment loading can exacerbate regional subsidence, thereby increasing the relative sea level. Glacial isostatic adjustment crustal motion (both uplift and subsidence) arises from the delayed response to past ice mass changes, where the Earth's mantle responds as a viscous fluid (e.g., Simon et al., 2016), and to the present-day, instantaneous elastic response to present-day ice mass change (e.g., Jiang et al., 2010) due to changing surface ice mass loads. In coastal areas where accelerated glacial wasting has been reported, the elastic component of glacial isostatic adjustment results in a relative rise in ground level and concomitant fall in relative sea level.

Local-to-regional scale subsidence and uplift resulting from changes in groundwater or porewater pressures occur in areas that are underlain by compressible and elastically deforming soils responding to groundwater fluctuations. Cohesive soils commonly exhibit seasonal changes in moisture content that can be associated with local subsidence or uplift (e.g., Simic et al., 2015). Anthropogenic impacts on ground level, primarily result from dewatering for potable supply or for subsurface mining or engineering (Cigna et al., 2017).

Metrics and numerical limits

Global sea-level rise was of the order of 1.3 mm/yr early in the 20th century (1901 to 1971) but has recently increased to about 3.7 mm/yr (2006 to 2018) (IPCC, 2021). Relative sea-level change varies considerably, depending on vertical land motion and other factors. Where the land is subsiding due to compaction (which can arise from natural causes or from groundwater pumping) isostatic subsidence or mantle downwelling, relative sea-level may be much larger than the global values, while in regions that are rapidly uplifting (e.g., Iceland, Hudson Bay (Canada), Fennoscandia, Glacier Bay (Alaska, USA), Patagonia (Chile)), relative sea-level has been falling and is projected to continue to fall. High rates of uplift in Iceland (25–29 mm/yr) have been related to glacial isostatic adjustment (Schmidt et al., 2013). It should be noted that coastal regions may also subside because of human activities (e.g. Bateson et al. 2023).

The size and spatial extent of surface rupture, fissures and uplift/subsidence associated with earthquakes depends on the type, magnitude and depth of the earthquake as well as the distance from the earthquake (Biasi et al., 2006).

Rates of uplift in the Himalayas are reported to be in the order of 1 cm/yr (USGS, 2015). Tectonic uplift and subsidence are generally as large or larger than the displacement of the surface rupture; moderate to large earthquakes in the crust that do not rupture to the surface will still broadly warp the region. The magnitude of the displacement will decrease with increasing distance from the earthquake, but in the case of ruptures on inclined faults such as subduction zones (rather than vertical strike-slip faults) uplift or subsidence of at least 1 m may extend for more than 200 km from the fault trace for the largest earthquakes (Styron, 2019). Both effects will extend along the length of the seismically active fault, a distance of a few kilometres for Magnitude 6 earthquakes to more than 1000 km for Magnitude 9 earthquakes.

Ground-level response to groundwater dewatering is a global issue. Subsidence values of up to 53 mm/yr have been determined using InSAR monitoring of Kabul (Meldebekova, 2020) and in Indonesia (Rygus et al., 2025).

Key relevant UN conventions and multilateral treaties

Sendai Framework for Disaster Risk Reduction 2015-2030 (UNDRR, 2015).

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Subsidence and uplift are driven by a variety of natural and anthropogenic processes (described in detail above), which include mining or tunnelling, consolidation, sinkholes, groundwater fluctuations, moisture changes on expansive soils, groundwater extraction, tectonic processes, volcanic unrest, and isostatic changes from sediment or ice loading or removal, and mantle flow.

In volcanic environments, uplift is typically associated with pressurisation ('inflation') of a shallow (a few kilometres beneath the surface) magmatic system caused by the injection of magma but may also be caused by the volatile degassing of a magma body. Subsidence is associated with depressurisation ('deflation') of a magmatic system and may be caused by magma cooling and solidification, or the outflow of magma (during eruption or lateral migration into dykes or sills, e.g., Sigmundsson et al., 2015).

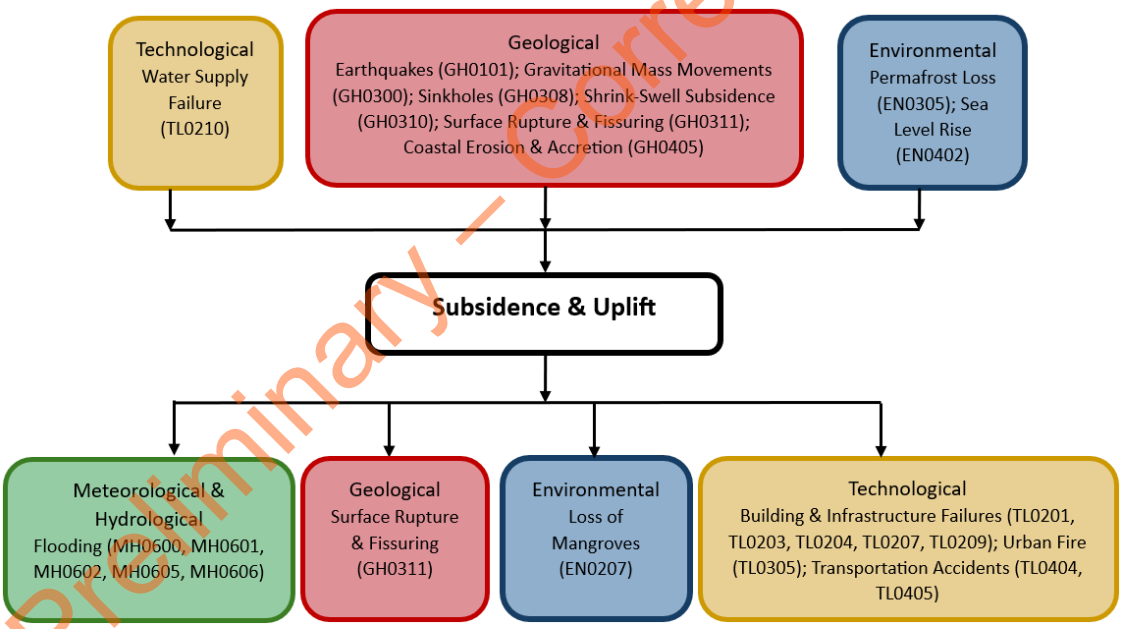
Preliminary – Corrections Pending

Impacts: Damage can be caused to buildings, roads, dams, and utility infrastructure (e.g., gas and water lines). In addition to the immediate, local risk posed by collapsing infrastructure, this damage may hamper rescue and rebuilding efforts by impeding transportation and utility delivery. In the worst cases, damage to lifelines may cause local flooding (e.g., water lines), environmental impacts (e.g., oil pipelines) and even highly destructive fires (gas lines) that may be more damaging than the initial earthquake. Potential also exists for disruption due to flooding or re-routing of rivers if the river channel has been sufficiently modified (Holbrook and Schumm, 1999).

Volcanic unrest associated with uplift and/or subsidence may cause significant damage and distress to residents, with associated evacuations causing permanent displacement for some and loss of livelihoods (e.g., Barberi et al., 1984). A risk perception study at Campi Flegrei showed that residents who remembered the unrest episodes of the 1970s and 1980s were more concerned about unrest than an eruption (Ricci et al., 2013). Testing and practising evacuation procedures for future response may enhance the awareness and preparedness of populations (e.g., Commune di Napoli, 2019).

Tectonic uplift and subsidence are not generally destructive, with the exception of coastal areas. For example, particularly large subduction zone earthquakes can cause persistent (decades-long) or permanent reconfigurations of a coastline. Uplift during a mega-thrust earthquake can lead to dramatic decreases in the depth and utility of harbours. Subsidence during a Magnitude 8-9 subduction zone earthquake can cause coastal communities, highways, and other infrastructure to sink below sea level and the establishment of a new shoreline inland by several tens to hundreds of meters.

Multi-hazard Context: The figure below summarises common interactions between subsidence & uplift and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



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Monitoring: The section and the table below offer an overview of monitoring subsidence & uplift. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	No Information Available
How is the Hazard Observed/Monitored/Forecast?	Commonly using InSAR and GNSS stations, for instance in monitoring of pipelines and volcanic regions.

Risk Management: Before eruptions, uplift and/ or subsidence may be among the first signs that a magmatic system is restless, so monitoring and understanding ground deformation is critical to attempts to understand magmatic systems, forecast eruptions and mitigate volcanic risk (Dzurisin, 2007).

While no technology exists for reducing these or other earthquake hazards, the risk to infrastructure posed by surface rupture and fissures can be mitigated to some degree by not building on known fault traces, seismic retrofitting of existing buildings, and engineering of pipelines with enough flexibility to absorb the displacement by bending and shearing, rather than breaking (e.g., USGS, 2003).

Coastal change can impact harbour water depth and damage infrastructure. In these zones, modelling to enable adaptive planning is the best form of mitigation (Steven et al., 2020).

In areas where stopping anthropogenic groundwater dewatering leads to rising ground levels, as well as potential impacts on infrastructure, consideration should be given to impacts on water quality, such as where mine water rebound results in the mixing of mining and potable water (Boak et al., 2007).

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Preliminary – Corrections Pending

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Coordinating agency or organization

British Geological Survey

Preliminary – Corrections Pending

GH0310 / GEOLOGICAL / Ground Failure

Shrink-Swell Subsidence

Definition

Subsidence is a lowering or collapse of the ground, caused by various factors, including groundwater lowering, sub-urface mining or tunnelling, consolidation, sinkholes, or changes in moisture content in expansive soils. Shrink-swell is the term applied to the behaviour of expansive soils. These are a group of soils that exhibit volumetric change in response to changes in moisture content, such that they shrink in response to desiccation and swell by hydration, resulting in ground subsidence and ground heave respectively (BGS, 2020).

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BGS, 2020. Swelling and Shrinking Soils. British Geological Survey (BGS). www.bgs.ac.uk/geology-projects/shallow-geohazards/clay-shrink-swell Accessed 27 September 2024.

Preliminary – Corrections Pending

Annotations

Synonyms

Problem soils, Expansive clay subsidence, Expansive soils, Clay shrink-swell, Clay-rich subsidence, Pipe clays (American term), Swelling soils, Shrinkable soils.

Additional scientific description

The properties of expansive soils are attributable to the presence of swelling clay minerals. These clays range in their potential to absorb water according to their different structures. Expansive clay groups with increasing susceptibility to swelling include kandites (e.g., kaolinite, haloysite), illites (e.g., phengite, glauconite), vermiculites and smectites (e.g., montmorillonite, talc). These minerals are a product of weathering, commonly formed on land and then transported to the oceans. Their distribution reflects the underlying source rock geology, its diagenesis and stress history (e.g., stress-induced smectite to illite transformations) and the nature of the weathering, for example, wet climates are associated with kaolinite-rich soils and dry environments are characterised by smectite clays (Environmental Characteristics of Clays and Clay Mineral Deposits (usgs.gov)).

Metrics and numerical limits

For the most expansive clays, expansions of 10% are common (Nelson and Miller, 1992). In the field, expansive clay soils are recognisable in the dry season by the deep cracks that form in roughly polygonal patterns, commonly known as mud cracks. The zone of seasonal moisture content fluctuation is usually the upper 1.5-2 m, but can be up to 5 m, of the subsurface (BGS, 2020). This creates cyclic shrink/swell behaviour in the upper part of the soil column, and cracks can

extend to considerable depths.

Soils can be tested using the Expansion Index which provides an indication of their swelling potential, which engineers can use to specify building design measures (ASTM D 4829).

Key relevant UN conventions and multilateral treaties

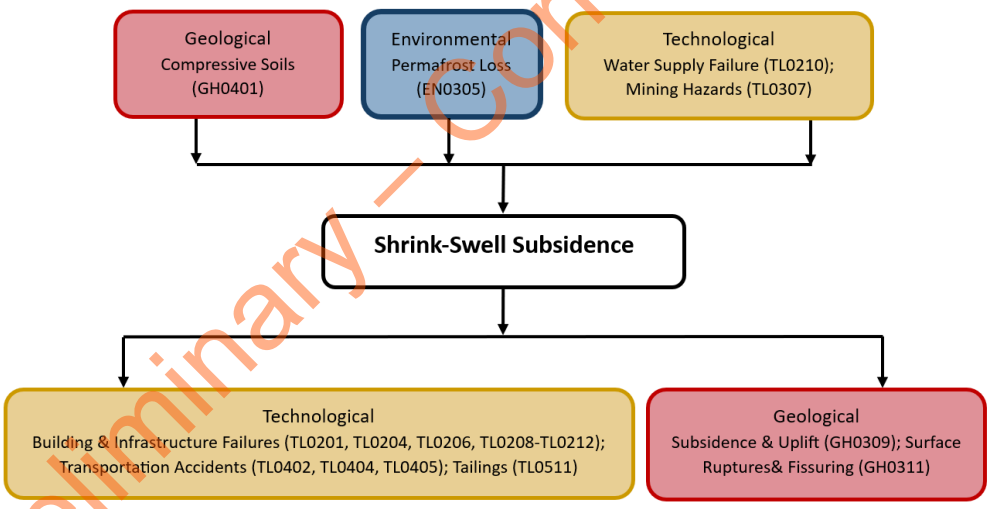
Not identified.

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Drivers of shrink-swell subsidence include groundwater lowering, groundwater extraction, subsurface mining or tunnelling, consolidation, sinkholes, heatwaves and drought cycles, or changes in moisture content in expansive soils.

Impacts: Beneath the depth of influence of atmospheric change in moisture content, the water demand of vegetation, particularly trees on clay soils dominates the moisture content changes that lead to the soil shrinking (subsidence) and swelling (heave). Where subsidence and heave occur beneath or close to properties and infrastructure this can result in damage (Florida Department of Environmental Protection, 2020). The most obvious way in which expansive soils can damage foundations is by uplift as they swell with moisture increases. Swelling soils lift up and crack lightly loaded, continuous strip footings, and frequently cause distress in floor slabs. Uplift is commonly differential, reflecting the different resisting forces across the structural foundations. Shrink-swell can influence structural stability during seismic events, resulting in infrastructure damage.

Multi-hazard Context: The figure below summarises common interactions between shrink-swell subsidence and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring river erosion & accretion. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	National Geological Surveys (e.g. British Geological Survey) often produce data regarding shrink-swell probability, occurrence and likelihood referring to bedrock and superficial geology, often in the context of a changing climate.
How is the Hazard Observed/Monitored/Forecast?	GNSS, InSAR, ground penetrating radar and soil moisture sensors are all used to monitor soil conditions.'

Preliminary – Corrections Pending

Risk Management: The extensive distribution of these soils across the world has necessitated characterisation through index testing to inform remedial measures. At its simplest, the plasticity indices are used to define inorganic clays with inherent swelling capacity (e.g., BRE, 1993). Expansion of soils can also be measured in the laboratory directly, by immersing a remolded soil sample and measuring its volume change or using LiDAR techniques (Hobbs et al., 2014) and Earth Observation applications (Jones et al,. 2023).

Prevention strategies include the use of non-expansive soils in construction or applying soil stabilisers to mitigate shrink-swell behavior before construction begins. However, the best way to avoid damage from expansive soils is to extend building foundations beneath the zone of water content fluctuation as modified to reflect the presence of vegetation (Rogers et al., no date).

Dramatic changes such as the clearing of vegetation associated with building plots on expansive soils should be limited to prevent change in soil behaviour (e.g., Jones, 2012).

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Coordinating agency or organisation

British Geological Society

Preliminary – Corrections Pending

GH0311 / GEOHAZARD / Ground Failure

Surface Rupture and Fissuring

Definition

Surface ruptures and fissures are localized ground displacements that develop in response to tensional, compressional, and shear stresses, most commonly in unconsolidated sediment, but also in rock (Arizona Geological Survey, 2020). Surface ruptures represent the upward continuation of fault slip at depth, while fissures are smaller displacements, or more distributed deformation in and around the rupture area (adapted from USGS, no date and PNSN, no date).

Preliminary – Corrections Pending

References

Arizona Geological Survey, 2020. Earth Fissures and Ground Subsidence. https://azgs.arizona.edu/center-natural-hazards/earth-fissures-ground-subsidence#:~:text=Earth%20Fissures%20are%20open%20ground,sinking%20of%20the%20Earth's%20surface Accessed 8 April 2025.

PNSN, no date. Surface rupture. Pacific Northwest Seismic Network (PNSN). pnsn.org/outreach/earthquakehazards/surface-rupture Accessed 8 April 2025.

USGS, no date. Surface faulting. United States Geological Survey (USGS). https://www.usgs.gov/faqs/what-surface-faulting-or-surface-rupture-earthquake Accessed 8 April 2025.

Annotations

Synonyms

Fault scarp, fault displacement, fault offset, tectonic fissures, ground deformation, surface faulting, coseismic subsidence, coseismic uplift, surface cracks.

Additional scientific description

Most earthquakes are caused by displacement (sliding) of the Earth's crust along a fault. The relative motion of the crust on either side of the fault results in persistent or permanent deformation of the Earth's surface, in addition to the ground shaking resulting from the sudden release of energy during the earthquake. Surface ruptures and fissures are manifestations of this longer-term deformation, and although less dramatic, may all pose hazards during and after earthquakes (Styron, 2019).

Natural or anthropogenic ground desiccation associated with subsidence can lead to ground fissuring. Tunnelling or mining can lead to subsidence and surface rupture, and /or fissuring. Ground fissures may also form as incipient indicators of land sliding, ground spreading or cambering, for example, induced by mining or karst subsidence.

Ayalew et al. (2004) suggested that ground fissures in the Ethiopian rift valley may be related to aseismic tectonic strain, piping and hydraulic compaction.

Surface ruptures and fissures can also occur in volcanic environments associated with volcanic earthquakes and ground deformation. For example, in November 2023, intense seismic swarms coupled with ground deformation associated with

a magmatic intrusion on the Reykjanes Peninsula, Iceland, led to surface rupture and fissuring in the town of Grindavík, damaging infrastructure including roads and pipelines (Icelandic Meteorological Office, 2023; De Pascale et al., 2024).

Metrics and numerical limits

The size and spatial extent of surface ruptures and fissures depend on the type, magnitude and depth of the earthquake, as well as the distance from the earthquake and local geological conditions.

Surface ruptures are expected in about half of continental magnitude 6 earthquakes, with an expectation that increases to 100% for continental earthquakes with magnitude 8 and larger (Biasi and Weldon, 2006). Displacements vary from a few centimetres for earthquakes at the low end of this range, up to 15-20 m for the largest possible continental earthquakes (Biasi and Weldon, 2006). Fissures are generally much smaller and more spatially distributed than surface ruptures.

Surface rupture and fissuring will extend along the length of the earthquake fault, which can extend from a few kilometres for magnitude 6 earthquakes to over 1000 km for magnitude 9 earthquakes.

In Arizona, fissures range from discontinuous hairline fractures to open ground cracks that exceed 3 km in length, up to 7 m wide, and tens of meters deep. In this context, fissure depth is likely to reflect the depth to the groundwater (Arizona Geological Survey, 2020).

Key relevant UN conventions and multilateral treaties

Not identified.

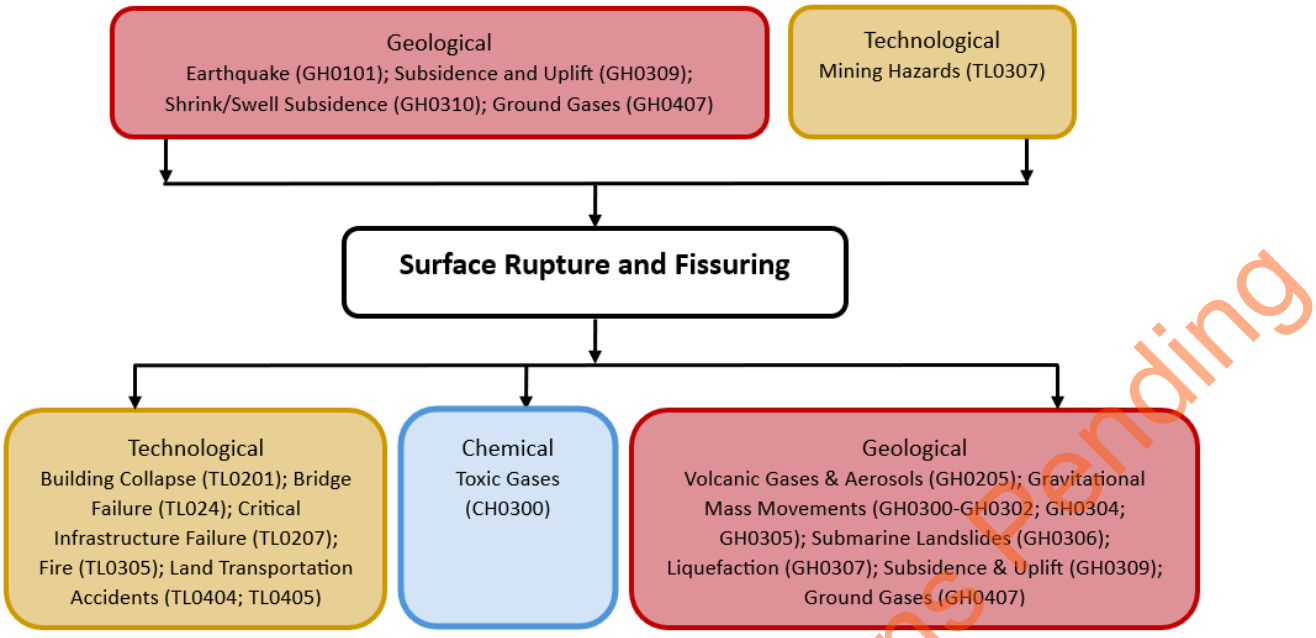
Examples of hazard drivers, impacts and risk management

Hazard Drivers: Earthquake surface ruptures and fissures are caused by earthquakes of sufficient magnitude and proximity to the Earth's surface to cause permanent ground deformation. Surface ruptures and fissures are generally limited to the area near the causative fault's intersection with the Earth's surface (Styron, 2019). Drivers of ground fissuring also include land sliding, ground spreading or cambering, for example, related to groundwater extraction or induced by mining or karst subsidence.

Impacts: Surface ruptures and fissures can cause loss of agricultural land and damage to buildings, roads, dams, and utility infrastructure (e.g., gas and water lines). In addition to the immediate, local risk posed by collapsing infrastructure, this damage may hamper rescue and rebuilding efforts by impeding transportation and utility delivery. In the worst cases, damage to lifelines may cause local flooding (e.g., water lines), environmental impacts (e.g., oil pipelines) and even highly destructive fires (gas lines) that may be more damaging than the initial earthquake. There is also potential for disruption due to flooding or re-routing of rivers if the river channel is sufficiently modified (Holbrook and Schumm, 1999). Livestock and wildlife injuries or death have been reported as well as impacts on humans (Arizona Geological Survey, 2020).

Multi-hazard Context: The figure below summarises common interactions between surface ruptures and fissuring and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

Preliminary – Corrections Pending



Preliminary – Corrections Pending

Monitoring: The section and the table below offer an overview of surface ruptures and fissuring. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Early warning systems for the main triggering hazard of surface ruptures or fissuring (i.e., earthquakes) are typically maintained by national organisations with the remit to monitor seismic activity (e.g., USGS for the United States).
How is the Hazard Observed/Monitored/ Forecast?	To monitor and activate alerts for the main triggering hazard of surface ruptures or fissuring (i.e., earthquakes), a network of seismic stations/sensors is required, ideally close to the regions where earthquakes are more likely to occur. Satellite-based monitoring tools (e.g., InSAR) have become increasingly valuable in detecting surface rupture before, during, and after seismic events.

Risk Management: Suggested remedial measures include reducing the dependence on groundwater by using alternative sources; planning to avoid fissures when constructing infrastructure or buildings; managing drainage to avoid losses into fissures and monitoring water infrastructure for flow reversal (Arizona Geological Survey, 2020).

While no technology exists for reducing these or other earthquake hazards, the risk to infrastructure posed by surface rupture and fissures can be partly mitigated by not building on known fault traces, seismic retrofitting of existing buildings, and the engineering of pipelines with enough flexibility to absorb the displacement by bending and shearing, rather than breaking (e.g., USGS, 2003).

There are no specific early warning systems for surface ruptures or fissuring. However, there are early warning systems for earthquake ground shaking. These systems can be useful to mitigate the impact of surface ruptures and fissuring, by allowing the population to take protective measures (the so-called *duck, cover and hold on* - (DCHO)), or to evacuate vulnerable buildings. See profile for Earthquakes (GH0101) for additional information.

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Coordinating agency or organisation

Global Earthquake Model (GEM) Foundation.

Preliminary – Corrections Pending

GH0401 / GEOLOGICAL / Other Hazards

Compressive Soils

Definition

Compressive soils are prone to volumetric change when subject to mechanical loading (USDA, 1990:30). Collapsible soils are metastable in that they are prone to volumetric change (collapse) on wetting and loading (Rogers, 1995).

References

Rogers, C.D.F., 1995. Types and distribution of collapsible soils. In: Derbyshire, E., T. Dijkstra and I.J. Smalley (eds), Genesis and Properties of Collapsible Soils. NATO ASI Series C, vol 468. Springer. doi.org/10.1007/978-94-011-0097-7_1

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Preliminary – Corrections Pending

Annotations

Synonyms

Consolidation, Compaction, Settlement, Poaching, Land/soil degradation, Peat shrinkage, Thermokarst.

Additional scientific description

Volume change when a soil is subject to loading, due to changes in pore volume, is a result of the loss of air and water from the voids, and then as a consequence of more ordered grain packing or destroying of some larger soil pores by worms or dead roots. Organic matter in the soil may be more easily compressible; organic-rich and peat soils being particularly susceptible to consolidation. Consolidation is the gradual reduction in soil volume resulting from an increase in compressive stress. The resulting increase in density is compaction (USDA, 1990).

Consolidation consists of 3 types: (1) an initial phase, which is a comparatively sudden reduction in volume resulting from the expulsion and compression of gas; (2) primary consolidation, which results principally from a squeezing out of water and is accompanied by a transfer of load from the soil water to the soil solids; and (3) secondary consolidation, resulting principally from the adjustment of the internal structure of the soil mass after initial consolidation. Settlement is the displacement of a structure due to the compression and deformation of the underlying soil. Compaction is the densification of a soil by means of mechanical manipulation (USDA, 1990).

Collapsible soils differ from compressible soils in that they are low density soils with a structure that collapses upon wetting and arrangement of particles reformed. They may have considerable strength when dry or moist. They lose strength and undergo sudden compression when they are saturated. Some will collapse under their own weight when saturated; others, only when loaded (USDA, 1990).

Thermokarst is a type of terrain characterized by very irregular surfaces of marshy hollows and small hummocks formed when permafrost-affected soils thaw. Small domes that form on the surface due to frost heaving with the onset of winter collapse during the following summer thaw, leaving surface depressions.

Compressible soils can be characterised using consolidation testing in the laboratory and in the field using static cone testing, penetrometers and bulk density rungs (USDA, 1990).

Metrics and numerical limits

Comprehensive assessments of compacted / compressive soils are lacking. The Intergovernmental Technical Panel on Soils (ITPS) and Food and Agriculture Organization of the United Nations (FAO) indicated that compaction-related soil degradation is increasing in Asia, Latin America and the Near East and North Africa; it is variable in Europe and Eurasia, the SW Pacific and North America (FAO and ITPS, 2015).

The FAO and its partners in the Global Soil Partnership (GSP) are designing SoilSTAT, a system for monitoring, forecasting and reporting periodically on the status of global soil resources. The name of the system mirrors the FAOSTAT family of global status databases and monitoring. SoilSTAT is part of the Global Soil Information System. It will be built under GSP Pillar 4 as part of the spatial data infrastructure for the exchange of web-based soil data services. The basic data elements of Pillar 4 include soil profiles, soil polygon maps and soil grids; SoilSTAT will be based on indicators describing the current condition of, and trends in, soil quality. According to the Status of the World's Soil Resources report, indicators will address soil threats such as erosion, compaction, salinisation and the loss of soil organic matter. SoilSTAT will therefore be an important mediator in the harmonised reporting of national soil information for the Sustainable Development Goals (FAO and ITPS, 2015).

Key relevant UN conventions and multilateral treaties

United Nations Convention to Combat Desertification (UNCCD); Intergovernmental Technical Panel on Soils (ITPS)

Examples of hazard drivers, impacts and risk management

Hazard Drivers: The main cause of compaction is vehicle movements across the soil surface, with farm mechanisation considered the primary cause on both agricultural and forestry land, especially if soil moisture levels are high (Forest Research, 2020). Extensive compaction is also caused by livestock and herds of wild animals, especially if stocking densities are high. Soil compaction on construction sites occurs either deliberately when foundations and sub-grades are prepared for construction or as an unintended result of vehicular traffic and excavation (cut and fill) works (DEFRA, 2006).

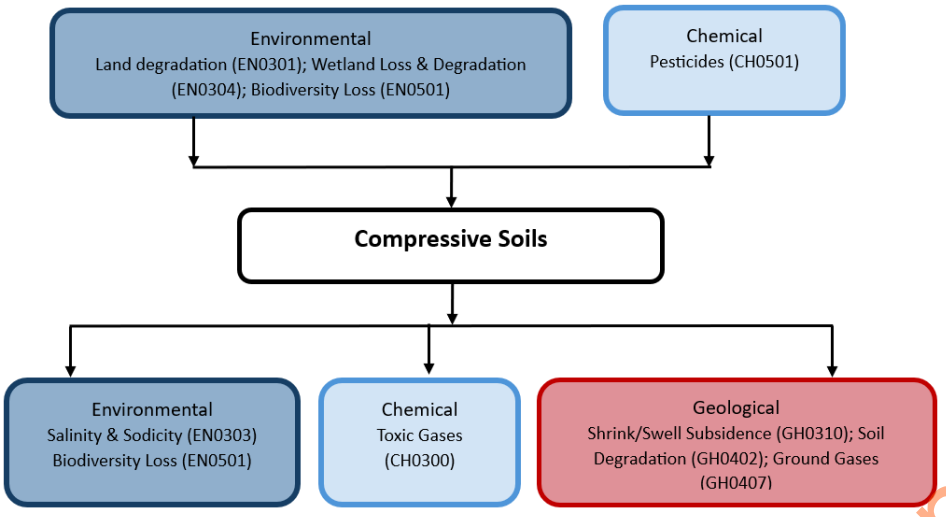
Impacts: Compaction reduces the volume of void available for water, potentially affecting water infiltration into soil, crop root moisture uptake and penetration, and consequential crop yield. Soil compaction can lead to surface ponding of water and water-logging, leading to chemical deterioration in soil quality. The potential for increased surface water run-off can lead to soil erosion (USDA, 1990).

Collapsible soils commonly occur as alluvial fans in sub-humid to arid areas. Consequential threats include salinisation, nutrient imbalance and loss of biodiversity that may result from soil compaction. Compacted soil may contribute to atmospheric warming through increased emissions of carbon dioxide, methane and nitrogen dioxide from such soils (USDA, 1990). Significant shrinkage of organic soils can occur during their drainage, compression and decomposition. Drainage of peat results in ongoing land subsidence and carbon loss. Subsidence is the gradual lowering of the land surface due to the drained peat shrinking, consolidating and becoming denser.

Collapsible soil foundations cause problems when they are saturated after being loaded by a structure. Examples are settlement of a dam foundation resulting in cracking of the dam when stored water saturates the foundation; settlement and cracking of an irrigation ditch, dike or lining when seepage from the ditch saturates the foundation; or settlement of a building when the foundation soil is saturated with water from a downspout or leaks in water or sewer pipes (USDA, 1990).

Multi-hazard Context: The figure below summarises common interactions between compressive soils and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

Preliminary – Corrections Pending



Monitoring: The section and the table below offer an overview of monitoring compressive soils. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Land management agency
How is the Hazard Observed/Monitored/Forecast?	Soil physical property analysis

Risk Management: Compressible soils commonly occur in river estuaries where they may be associated with flooding. Building in these areas may necessitate the use of building platforms to avoid flooding. However, loads with shallow foundations may be subject to large settlement over long durations. Methods such as the installation of sand drains can be used to manage the settlement. Where the compressible soils are relatively thin, foundations may be taken down to bear into more competent strata at depth. This scenario can lead to differential settlement. These soils are also sensitive to ground lowering as a consequence of dewatering (USDA, 1990).

For organic soils, drainage should be avoided and rewetting as a restoration process. Traffic on organic soils should be avoided. For mineral soils, animal loads and traffic should be reduced, especially in wet conditions.

Many loessal soils are collapsible because of their soil particle bonding structure. Low-density soils above the water table in this situation should be suspected of being collapsible. They can be identified by modified consolidation testing of undisturbed samples. In testing, samples are loaded in a moist condition, then saturated collapsible soils will show sudden settlement upon wetting (USDA, 1990). For example, it is important to check the foundations of earth dams for strength, permeability, compressibility, dispersive clays (piping), water table elevation, and depth to bedrock (USDA, 1990).

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Coordinating agency or organisation

British Geological Survey.

Preliminary – Corrections Pending

GH0402 / GEOLOGICAL / Other Hazards

Soil Degradation

Definition

Soil degradation is defined as a change in soil health status resulting in a diminished capacity of the ecosystem to provide goods and services for its beneficiaries (FAO, 2020).

Reference

FAO, 2020. FAO Soils Portal Key definitions. Food and Agriculture Organization of the United Nations (FAO). www.fao.org/soils-portal/about/all-definitions/en Accessed 2 October 2024.

Preliminary – Corrections Pending

Annotations

Synonyms

Land degradation.

Additional scientific description

Soil degradation is the reduction in soil health as a result of changes in physical, chemical and biological conditions that affect the soil's capacity to function as a vital living system and to provide ecosystem services (adapted from Soil Monitoring Law).

Degradation can result in the total loss of the soil body as well as a decline in biodiversity, organic matter, soil fertility and structural condition leading to increased risk of erosion or excessive flooding. Soil degradation can be a natural process or the result of inappropriate or unsustainable land management practices. Soil degradation processes include: water erosion (e.g. sheet, rill and gully erosion); wind erosion; increased salinity (includes dryland, irrigation and urban salinity as well as seawater incursions in coastal areas); the effects of pollutants; and structure decline (includes soil compaction and surface sealing). These processes can occur individually or together.

The strong relationship between soil health and food security calls for strategic and immediate actions, especially at the local level, to reverse soil degradation in order to increase food production and alleviate food insecurity in the areas where it is most needed and in the context of climate change (FAO, 2015). In addition, healthy soils play a vital role in regulating both the Earth's climate and water cycle. Soil degradation can affect the capacity of soils to store carbon, increase greenhouse gas emissions and reduce resilience to extreme weather events.

Soil is an essential component of 'land' and 'ecosystems' that both are broader concepts encompassing vegetation, water and climate in the case of land, and in addition to those three aspects, also social and economic considerations in the case of ecosystems. Degraded soils have a health status such that they do not provide the normal goods and services of the particular soil in its ecosystem (FAO, 2020).

Metrics and numerical limits

Soils with soil organic carbon (SOC) levels below the critical threshold of 10 to 15 g/kg (1.0%-1.5%) are typically considered degraded (Lal, 2015).

Land or soil degradation can be assessed using remote sensing. Satellite observations can provide proxies of land degradation such as severity, temporal development and areal extent (Olsson et al., 2022). Various indices have been used to assess land conditions such as Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), and Plant Phenology Index (PPI) (see Olsson et al., 2022). The NDVI is used to assess the health and density of vegetation and is a widely accepted proxy for assessing soil degradation.

Key relevant UN conventions and multilateral treaties

United Nations Convention to Combat Desertification (UNCCD), (UNCDD, 1994); United Nations Convention for Biological Diversity; United Nations Framework Convention on Climate Change

Examples of hazard drivers, impacts and risk management

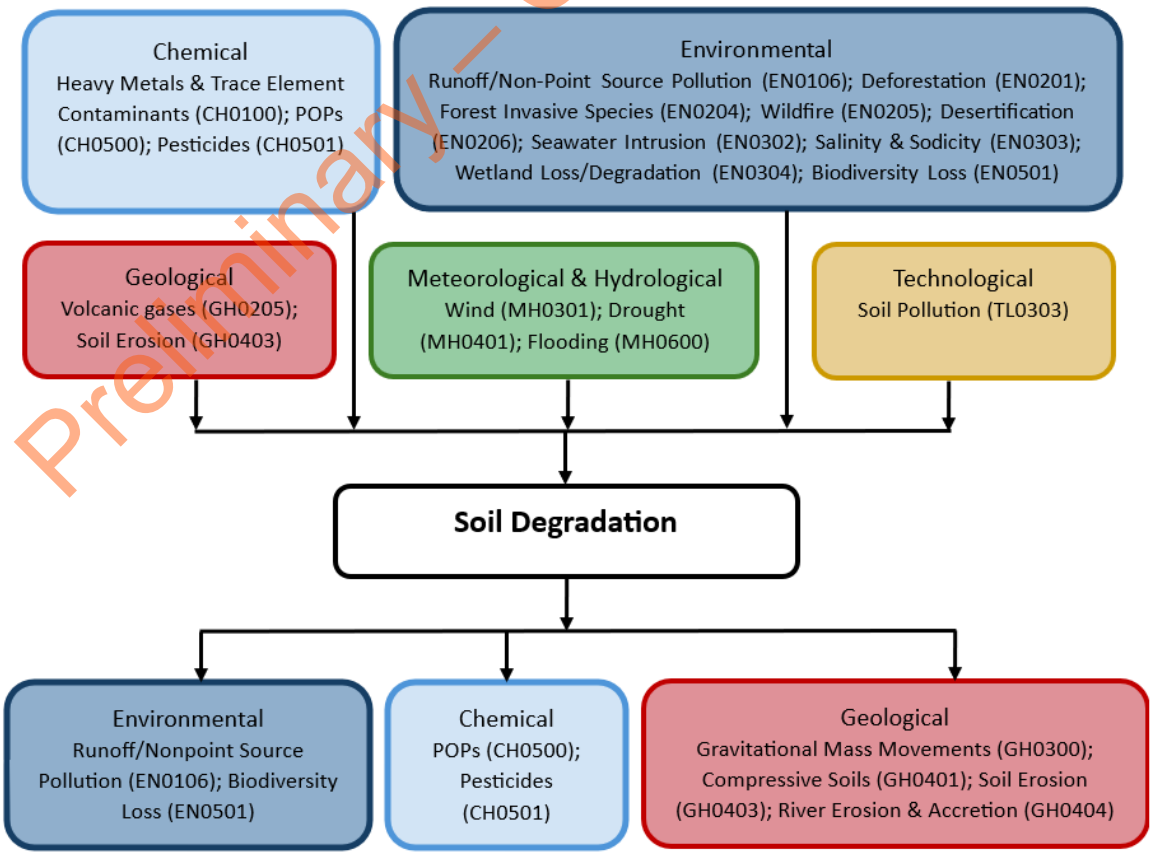
Hazard Drivers: Anthropogenic drivers of soil degradation include increasing consumer demand, urbanization, industrialization, and competition for land. These in turn result in a range of pressures such as intensive agriculture (imbalance fertilization, over-tillage), soil sealing, soil salinization by irrigation, deforestation, wildfires and pollution. Air pollution can affect semi-natural areas and urban soils, where risk management is focused on waste streams or industrial emissions. Studies on antibiotics in the soil environment have revealed that antimicrobials affect soil microbiomes which in turn may affect their quality, driving soil degradation (Cycoń et al., 2019).

Climate-related drivers of land or soil degradation include short-intensive rainstorms to gradual increases in temperature, precipitation and wind (Olsson et al., 2022). Climate change is amplifying soil degradation through increasing temperature, changing rainfall patterns and intensification of rainfall (Olsson et al., 2022).

Impacts: Soil degradation can lead to increased soil erosion, loss of organic matter, nutrient depletion, accumulation of salts and harmful contaminates, and reduction in biodiversity (Soil Atlas, 2024). Around 30% of the world's soils are moderately to highly degraded. Forty percent of these degraded soils are located in Africa and most of the rest are in areas that are afflicted by poverty and food insecurity (Soil Atlas 2024). It is estimated that at least 60% of the soils of the EU are affected by one or more degradational processes (EU Soil Observatory, 2024).

Most future land degradation is predicted to occur in the areas with the largest amount of arable land remaining. If current trends continue, experts estimate that by 2050, more than 90% of the Earth's land areas will be substantially degraded, 4 billion people will live in drylands, 50-700 million people will be forced to migrate, and global crop yields will be reduced by an average of 10% and up to 50% in some regions (Nachtergaele et al., 2012 cited by Little, 2019; IUCN, 2015; Gomiero, 2016; IPBES, 2018).

Multi-hazard Context: The figure below summarises common interactions between soil degradation and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Preliminary – Corrections Pending

Monitoring: The section and the table below offer an overview of monitoring soil degradation. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Land services, Soil and water conservation agencies, environmental agencies, etc.
How is the Hazard Observed/Monitored/Forecast?	Measurement of land surface for soil erosion, sediment concentration of flow for soil erosion, soil analysis for soil salinity, etc.

Risk Management: For agricultural soils, risk management through agroecology is adopted, which starts by restoring soil life to re-establish and/or enhance the multiple soil-based biological processes (FAO, 2015). This requires:

- *Increasing and monitoring soil organic matter*: Soil organic matter is considered the most common deficiency in degraded mineral soils and the main indicator for soil quality. Practical, accessible indicators can support local decisions and larger landscape monitoring and analyses for district level implementation.
- *Facilitating and monitoring of soil biodiversity*: Soil biological communities are directly responsible for multiple ecosystem functions.
- *Building on local farmers' knowledge*: Participatory scientific approaches to soil ecosystem management, such as Farmer Field Schools, are of great importance to inform farmers' knowledge with researchers' scientific principles in order better locally adapt agroecological systems.
- *Widescale adoption of sustainable soil management practices.*

Agroforestry systems can reduce soil erosion by as much as 100 times on steep slopes. Growing Faidherbia albida in association with millet (Pennisetum glaucum) increased grain yields by 50% in Burkina Faso and Senegal. In Honduras, the adoption of soil conservation practices tripled or quadrupled maize yields for 1200 families (FAO, 2015).

The FAO and its Global Soil Partnership launched a new program to boost soil productivity and reduce soil degradation for greater food and nutrition security in Africa. The recently adopted Africa Union Soil Initiative for Africa provides a long-term framework to guide investments and efforts to improve the health and resilience of Africa's soil (FARA, 2020).

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Coordinating agency or organisation

Food and Agriculture Organization of the United Nations.

Preliminary – Corrections Pending

GH0403 / GEOLOGICAL / Other Hazards

Soil Erosion

Definition

Erosion is the wearing away of the land surface by water, wind, ice, gravity or other natural or anthropogenic agents that abrade, detach and remove soil particles from one point on the Earth's surface, for deposition elsewhere. Four main forms are recognized: water, wind, harvest and tillage. (cf. FAO, 2020).

Reference

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Preliminary – Corrections Pending

Annotations

Synonyms

Wind abrasion. Dissolution. Soil loss.

Additional scientific description

Soil erosion is a slow-onset process that occurs naturally under all climatic conditions and on all continents but is significantly increased and accelerated by unsustainable or inappropriate human activities through intensive agriculture, deforestation, overgrazing and land use changes. The Status of the World's Soil Resources report identified soil erosion as one of the major global soil threats (FAO, 2015). Soil erosion rates are generally much higher than soil formation rates; as soil is a finite resource, its loss and degradation through erosion is not recoverable within a human lifespan (FAO, 2020).

Soil erosion decreases soil quality and functions, agricultural productivity, anddegrades ecosystem functions, amplifying hydrogeological risks such as landslides or floods. Soil erosion can cause significant losses in biodiversity, damage to human infrastructure and, in severe cases, leads to displacement of human populations (FAO, 2020).

Soil erosion poses a major threat to global food security and to the achievement of the Sustainable Development Goals (SDGs) (UN, 2015) on ensuring the well-being of at least 3.2 billion people around the world (FAO, 2020).

Generally, four types of soil erosion are recognized: (1) water; consisting of raindrop or splash, sheet, rill, and gully; (2) wind; (3) harvest; and (4) tillage.

- Splash erosion is caused by raindrops falling onto the soil surfaces causing small particles to move. The detached particles may form a crust that is easily removed by rain or winds.
- Sheet erosion occurs when the thin upper portion of the soil is displaced due to surface runoff after heavy rain. During this process, nutrients and organic matter are lost. This type of soil erosion is gradual and often goes unnoticed until larger portions of soil are displaced through the development of rills or the evidence of exposed roots.
- Rills are shallow drainage channels that form as rainwater flows into depressions in the soil surface. Over time, depressions can widen during subsequent precipitation events, which, in turn, increase susceptibility to erosion.
- Gully erosion occurs when runoff flows strongly and is concentrated in one location. In many cases, gullies begin as a rill that transitions into small channels. As water picks up energy, gully slopes become steeper. This type of soil

erosion is very visible and damaging. It often has a drastic effect on the productivity of the soil and can make the land unusable. Gullies can range from 2m to 10-15m in depth.

- Tillage erosion occurs in cultivated fields due to the movement of soil by cultivating the soil (e.g. ploughing). Tillage erosion is often denoted by thinner soils on the upper slopes of cultivated fields or a loss of soil downslope of field boundaries.
- Soil erosion due to crop harvesting generally occurs during harvesting of root crops such as potato, sugar beet, carrot or chicory roots. During the harvest, soil particles stick to the crops and are removed from the field.

Metrics and numerical limits

Approximately 7.5 million km^2 (6.1% of the global land surface) exceeds a generic tolerable soil erosion threshold of 10 Mg ha/yr (Borrelli et al., 2022). South America shows the highest prediction of average soil erosion rate (22.0 Mg ha/yr) in 2019, followed by Africa (17.1 Mg ha/yr) and Asia (12.8 Mg ha/yr) (Borrelli et al., 2022). North America, Europe and Oceania show considerably lower predicted values, totalling 11.0, 2.6 and 2.7 Mg ha/yr, respectively (Borrelli et al., 2022). A total of 75 billion tons of fertile soil is removed every year from the global soilscape by erosion. As a result, precious soil resources, which should be preserved for future generations, are continuously reduced. Every year approximately 12 million ha of land are lost (FAO and IAEA, 2017).

Climate projections, for all global dynamics scenarios, indicate a trend moving towards a more vigorous hydrological cycle, which could increase global water erosion (+30 to +66%; Borrelli et al., 2020).

Key relevant UN conventions and multilateral treaties

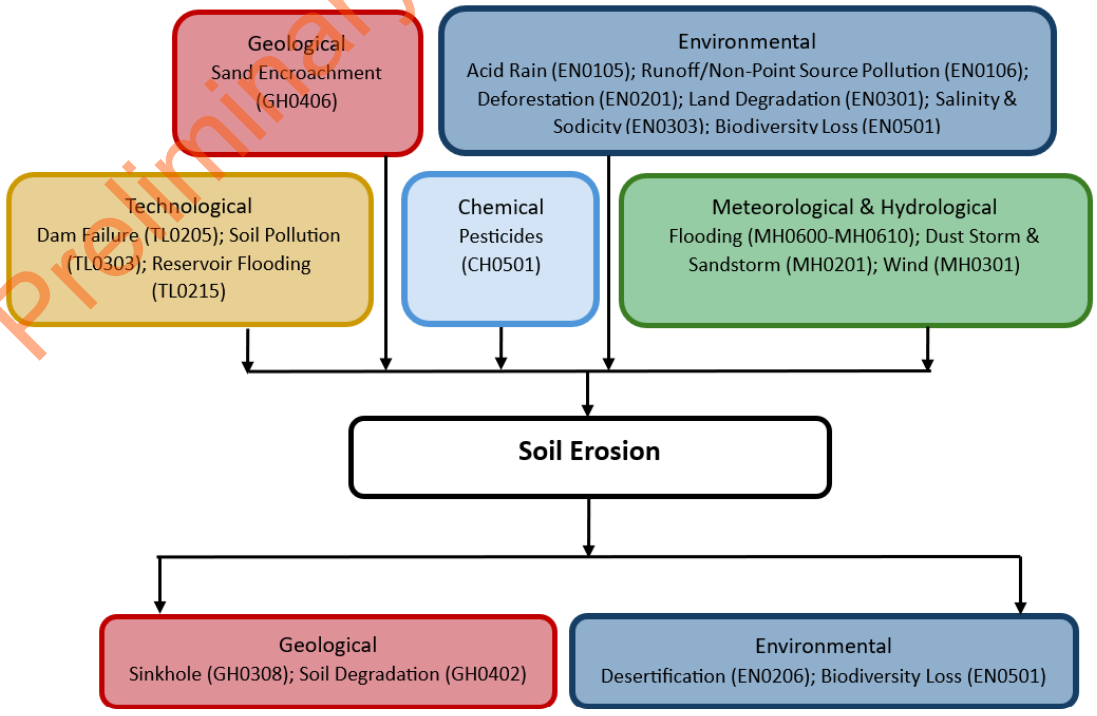
Food and Agriculture Organization of the United Nations (FAO) Global Soil Partnership (GSP) (FAO, 2012); United Nations Convention to Combat Desertification (UNCCD, 1994).

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Soil erosion is significantly increased and accelerated by intensive agriculture, deforestation, overgrazing and improper land use changes.

Impacts: Loss of soil body, fertility loss, desertification, off-site effects (e.g., sedimentation, siltation and eutrophication of water ways or enhanced flooding). Disruption of soil carbon and nutrient cycling. Affects climate and water regulation.

Multi-hazard Context: The figure below summarises common interactions between soil erosion and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



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Monitoring: The section and the table below offer an overview of monitoring soil erosion. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. GSP FAO
How is the Hazard Observed/Monitored/Forecast?	Measurement of the land surface; mass flux of a river or section

Risk Management: With 95% of the food consumed globally comes from the soil, soil erosion mitigation through the application of sustainable soil management (SSM) is critical for protecting soil while ensuring a sustainable and food secure world (FAO, 2020).

Soil erosion can be reduced through a number of simple measures including maintaining a healthy, perennial plant cover, mulching (leaving crop residues on the soil surface), cover crops and crop rotation, reduced tillage, terraces on steep slopes and water bunds, contour ploughing, addition of wind breaks and/or shelter belts, and the use of buffer strips.

One of the key messages from the Assessment Report on Land Degradation and Restoration prepared by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services is to eliminate perverse incentives that promote degradation and to devise positive incentives that reward the adoption of sustainable land management practices in order to avoid, reduce and reverse land degradation (IPBES, 2018).

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Preliminary – Corrections Pending

Coordinating agency or organisation

Food and Agriculture Organization of the United Nations (FAO), British Geological Survey.

Preliminary – Corrections Pending

GH0404 / GEOLOGICAL / Other Hazards

River Erosion and Accretion

Definition

River erosion is the removal of material from the banks and beds of rivers and streams (cf. Lawler, 1993). River accretion is the formation of new land such as channel bars, sandbanks and deltas by sedimentation or changing river flow (after Islam and Guchhait, 2020 and Hasanuzzaman et al., 2024).

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Annotations

Synonyms

Riverbank erosion. Stream bank deterioration. Stream bank disintegration. Avulsion

Additional scientific description

Riverbank erosion occurs by three main mechanisms: fluvial scour (entrainment of bed and bank sediments due to hydraulic forces exceeding the resisting forces), mass failure (erosion caused when large volumes of sediment slide or topple from the bank) or subaerial erosion (processes external to the stream, e.g. groundwater seepage or cattle pugging). River energy, the primary driver for erosion and accretion, differs between, along, and seasonally within river systems. Erosion rates increase if the hydraulic force increases (i.e. the flow of water) and/or the resisting forces decrease (e.g. the removal of vegetation). Consequently, riverbank erosion and accretion are continuous processes, amplified by higher energy events such as flooding.

Stream erosion is also associated with river scour, whereby bed sediment is eroded and may be redistributed (accretion). River scour is commonly focused on changes in bedform, which may be natural or artificial. For example, the impacts of scour on bridge foundations and other engineered infrastructure are well documented (Ozaukee County, no date).

Preliminary - Corrections Pending

Background weathering that facilitates erosion includes processes that are subject to seasonality, and include flooding, precipitation, crack formation, cryogenic processes, poaching and anthropogenic changes to the natural geomorphology (Darby et al., 2007).

River erosion and accretion are natural processes; however, anthropogenic activities and climate change have substantially accelerated their rates (Koutalakis et al., 2024).

Metrics and numerical limits

Published data, e.g. Hooke (1980) have presented results that demonstrate a relationship between erosion rates (m/yr) and catchment area (km^2), with annual erosion rates ranging from 0.5 m to 1000 m for drainage areas of 4 to 1000,000 km^2, respectively.

Key relevant UN conventions and multilateral treaties

United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses (Watercourses Convention): Adopted in 1997, this convention provides a framework for the use and protection of international watercourses, promoting cooperation and equitable utilization of shared water resources.

Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention): Adopted in 1992, this convention aims to ensure the sustainable use of transboundary water resources, prevent and control water-related hazards, and protect ecosystems.

Sendai Framework for Disaster Risk Reduction (2015-2030)

Examples of hazard drivers, impacts and risk management

Hazard Drivers: River erosion is primarily driven by bank erodibility and water erosivity. River erosion is accelerated by flood events, however, antecedent conditions contribute to the conditioning of the riverbank (Darby et al., 2007). Conditions such as antecedent flow, (e.g. high water levels cause saturated banks which are less stable), periods of low flow (which can result in unstable dry and cracking banks) and the condition of the riparian zone (i.e. bedrock, or the presence and condition of riparian vegetation which provide reinforcement of the banks and reduce near bank velocities) contribute to the resistance of the bank to erosion. Erosion is also accelerated by activities such as sediment extraction, river modifications and livestock grazing (Wilkinson et al. 2022). In areas with cold climates, the movement of river ice during the spring thaw can result in river erosion.

River erosion and accretion are associated with a few triggering hazards. For example, river flooding leads to bank collapse; ground shaking also induces riverbank failure due to vibrating actions. Liquefaction through groundwater movement can trigger the weakening of the bank materials, leading to erosion. Moreover, some man-made hazards like deforestation, sand mining and dam failure trigger river erosion and accretion. Deforestation increases surface run-off potential with higher potential riverbank erosion with greater sediment loads to the river. Sand mining destabilizes the riverbed and bank causing the collapse of the bank. Dam failure results in the huge release of water from the reservoir triggering the swelling of the downstream river courses causing bank failure. Soil erosion or artificial removal of the topsoil induces the collapse of the bottom layer of the soil adjacent to the riverbank. Moreover, sediment flux from the soil erosion also escalates the river accretion process and develops channel bars due to the transport-limited conditions of the river (Islam and Guchhait, 2020).

Impacts: River erosion can result in significant land loss and damage to infrastructure. In South Asia, for example, Bhuiyan et al. (2017) reported that the rivers of Bangladesh are responsible for cumulative annual erosion of up to 10,000 hectares of land. In addition to floodplains and settlements, Bangladesh also loses several kilometres of roads, railways, and flood control embankments each year (Bhuiyan et al., 2017). Widespread land loss, declining per capita income, livelihood crisis, and community conflicts are often reported in the lower Ganga plains (along the Bhagirathi-Hooghly River) in India (Islam and Guchhait, 2017).

In addition to the loss of land and infrastructure, the consequences of stream erosion and riverbank mass wasting are increased suspended sediment loads in streams, which impacts on water quality with consequential implications for human and ecological health (Grove et al., 2015). This includes detrimental impacts on aquatic, terrestrial and semi-aquatic ecosystems (Zaimes et al., 2021).

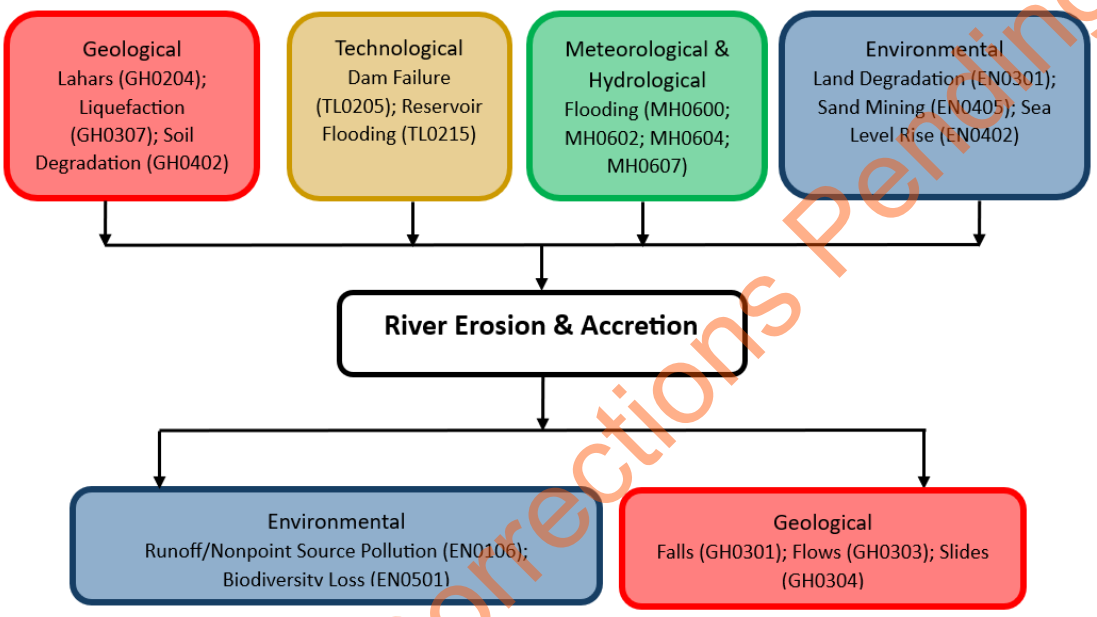
River accretion can create navigation issues, increase flooding risks, and disrupt natural habitats.

Sea level rise in the wake of climate change is expected to exacerbate the inundation of low-lying areas with swelling of the river courses and bank failure. The foremost visible loss due to riverbank erosion is the financial shock induced by the

Preliminary – Corrections Pending

agricultural land loss, engulfment of settlements and creation of the homeless and environmental refugees in areas of frequent erosions and accretion (Islam and Guchhait, 2024). The emergence of sand bars due to the deposition of riverine sediments can become a source of social conflicts and violence (e.g. Zaman, 1991).

Multi-hazard Context: The figure below summarises common interactions between river erosion & accretion and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring river erosion & accretion. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Local/state/national disaster management authority
How is the Hazard Observed/Monitored/Forecast?	Common methods for monitoring river siltation include drilling and profile measurement, acoustic and ultrasonic techniques, and intelligent mobile monitoring platforms. In addition, there are also comprehensive evaluation methods for river erosion and siltation, such as hydrological sediment models and time-series dynamic models. Specific instruments/models are: use of erosion pins, Photo Electronic Erosion Pin (PEEP) and PEET-3T, Total station and Terrestrial laser scanner- LiDAR, Bank Assessment of Non-point Source Consequence of Sediment (BANCS), bank erosion hazard index (BEHI) and near bank stress (NBS), The Bank Stability and Toe Erosion Model (BSTEM), Dynamic SedNet Stream Bank Erosion model and Numerical modelling using DSAS model.

Risk Management: River erosion and accretion monitoring and assessment requires a good understanding of these processes; however, they can be highly temporal and spatially complex (Koutalakis et al., 2024). Various methods and tools can be applied to study and monitor stream bank erosion and accretion including field mapping, remote sensing, erosion pins, and laser scanners (see Koutalakis et al., 2024 for more details).

Riverbank vegetation, for example mangroves, contributes to riverbank resilience to erosion, as do alluvial sediments. Mitigation of the impacts of bank erosion includes planning and avoidance, and soft and engineered protection or renaturing. Some examples are presented by the Scottish Environment Protection Agency (SEPA, 2020) and the Reef Trust, Commonwealth of Australia (Wilkinson et al, 2022).

Preliminary – Corrections Pending

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Coordinating agency or organisation

British Geological Survey.

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GH0405 / GEOLOGICAL / Other Hazards

Coastal Erosion and Accretion

Definition

Coastal erosion is the process of removal of material at the shoreline which leads to the loss of land as the shoreline retreats landward. Coastal accretion is the product of the deposition of material at the shoreline which leads to the gain of land as the coast advances seaward (Gibb, 1978).

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Annotations

Synonyms

Shoreline change, Coastal change (DCLG, 2010), encroachment.

Additional scientific description

Coastal erosion and accretion hazards, physically expose coastal areas to the risk of property damage, loss of life, and environmental degradation (c.f. Schwartz, 2005). The coastal zone, extending between fully terrestrial environments and marine environments unaffected by waves, is a dynamic setting which is subject to constantly changing energy inputs. Land-based processes deliver sediment to coastal environments where they are mobilised and transported by nearshore and wider marine processes. Rates of coastal erosion reflect the consequences of environmental change (human modifications and climate change) superimposed on natural variability in the underlying process-driven rates of erosion (Mentaschi et al., 2018). The landward movement of the coast through erosion can be as high as several metres per year but may be mitigated by sediment accretion. Understanding patterns of sediment migration is fundamental to modelling coastal change. Coastal change processes are wide-ranging; both marine and land processes present hazards to coastal environments including infrastructure, business, people, and ecosystem services in the coastal zone (Wong et al., 2014; Mentaschi et al., 2018).

Marine processes are largely governed by tides, tidal range, tidal surges, coastal flooding, waves, tsunamis, long-shore transport and a range of types of currents. Landsliding processes include falls, topples, slides and flows reflecting the local geological and groundwater conditions. Groynes, jetties, seawalls, breakwaters, rip-rap, and other anthropogenic structures and practices have a major influence on coastal change. For example, Mentaschi et al. (2018) found that dams are among the most prominent contributors to erosion because they retain sediment that would otherwise naturally supply the coastal zone with beach sediment.

Sediment and global sea-level rise impact on coastal erosion and accretion. Sediment loading can exacerbate regional subsidence, thereby increasing the relative sea-level rise. In coastal areas where accelerated glacial wasting has been reported, glacio-isostatic rebound results in a relative rise in ground level, as exemplified in the wasting of the Laurentide Ice Sheet (Simon

Preliminary – Corrections Pending

et al., 2016)

Subduction zone earthquakes can cause persistent (decades-long) or permanent reconfigurations of a coastline and associated patterns of erosion and accretion. Uplift during an earthquake can lead to dramatic decreases in the depth and utility of harbours. Subsidence during a Magnitude 8-9 subduction zone earthquake caused coastal communities, highways, and other infrastructure to sink below sea level, and the establishment of a new shoreline inland by several tens to hundreds of metres (Plafker, 1965).

Metrics and numerical limits

Mentaschi et al. (2018) used satellite data to evaluate global coastal morphodynamics along horizontal 30m grids over the period 1984 to 2015. They established a land loss of 28,000 km2; gained land of 14,000 km2; an increase in the active zone (essentially the intertidal zone together with areas frequently inundated by fresh, brackish or marine waters) of 25,000 km2, and a loss in the active zone of 11,500 km2. The region with the highest change per unit area over the time period was the Caspian Sea with an average cross-shore erosion of 600 m, followed by southern Asia, Pacific Asia, South America, eastern Africa and western Australia with an average cross-shore erosion of 50 m.

Key relevant UN conventions and multilateral treaties

The United Nations Convention on the Law of the Sea (UNCLOS) provides a comprehensive framework for the regulation of all ocean space, including the protection and preservation of the marine environment, which encompasses coastal erosion and accretion processes.

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Extreme weather events associated with high intensity storm surges and flooding as well as tsunamis, waves and currents which influence the extent and rate of erosion or accumulation of coastal landforms. Extreme rainfall events contribute to soil saturation and associated shear strength reduction associated with landsliding. Anthropogenic factors impact most significantly on sediment supply primarily through sediment retention.

Impacts: Coastal morphology, which is directly impacted by coastal erosion and accretion, heavily impacts the distribution and scale of other coastal hazards, including coastal flooding (MH0601), estuarine flooding (MH0602), storm surges (MH0703), storm tides (MH0704), tropical cyclones (MH0309), sub-tropical cyclones (MH0308), tsunami (MH0705), loss of mangroves (EN0207), sand mining (EN0405), sea-level rise and indirectly on hazards that have significant biological or health impacts, including harmful algal blooms (BI0603). Coasts have high population densities and significant investments in infrastructure and the built environment. Coastal development too frequently occurs with little consideration for coastal erosion or accretion. Despite the likelihood of climate change exacerbating them (IPCC, 2014), many densely populated regions of the world are being affected by these hazards.

The impacts of coastal erosion and accretion hazards are often compounded by coastal hazards with mainly biological or health impacts. These include harmful algal blooms (HABs) which occur when colonies of algae grow out of control while producing toxic or harmful effects on people, fish, shellfish, marine mammals, and birds. They commonly occur in nutrient (mainly phosphorus, nitrogen, and carbon) rich, poorly circulated waters. People often get sick by eating shellfish containing toxins produced by the algae. Airborne HAB toxins may also cause breathing problems and, in some cases, trigger asthma attacks in susceptible individuals. NOAA 2024.

Multi-hazard Context: The figure below summarises common interactions between coastal erosion & accretion and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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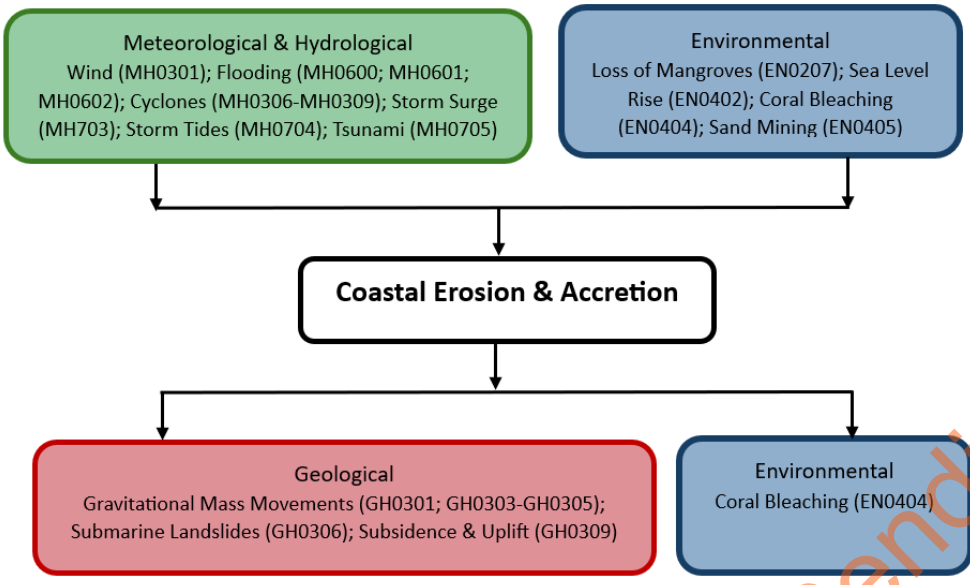

Monitoring: The section and the table below offer an overview of monitoring coastal erosion & accretion. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	National agencies (e.g. the European Marine Observation and Data Network; UK Environmental Agency in the UK).
How is the Hazard Observed/Monitored/Forecast?	Extensive mapping programmes

Risk Management: Coastal change poses a threat to coastal settlements, businesses and tourism. Coastal environments host a range of infrastructure, including the landing points for telecommunications, ecosystem services, and in the order of 40% of the world's population (Mentaschi et al., 2018). Coastal erosion becomes a hazard when society does not adapt to its effects on people, the built environment and infrastructure (UNDRR, 2017). Therefore, adaptation and adaptive pathways are key policies in managing coastal hazards. In some parts of the world, a range of engineered interventions have been successful in protecting specific infrastructure and populations, but the consequences of engineered intervention need to be fully appraised to avoid unplanned consequences. Engineered solutions vary widely, and include utilisation of rock armour, breakwaters, groynes, seawalls, wharfs and harbours, offshore barriers, a range of styles of revetments, beach nourishment or replenishment, mangrove protection and dredging (Climate-ADAPT, 2015). Coastal change can impact harbour water depth and damage infrastructure. In these zones, modelling to enable adaptive planning is one of the best forms of mitigation (Steven et al., 2020). It can also affect groundwater resources, such as saline intrusion (USGS, no date). Potential impacts are especially significant for atoll islands with shallow unsaturated zones. These islands are particularly susceptible to impacts on groundwater resources and populations (UNESCO, 2019).

Examples of regional and national programmes for coastal erosion and coastal change include the first pan-European shoreline-migration map, prepared by the European Marine Observation and Data Network (EMODnet, 2020) and the UK national coastal erosion risk map, prepared by the UK Environment Agency.

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Coordinating agency or organisation

British Geological Survey.

Preliminary – Corrections Pending

GH0406 / GEOLOGICAL / Other Hazards

Sand Encroachment (Dunes)

Definition

Sand encroachment is the accumulation of wind-borne sand. It commonly affects coasts, watercourses, and both cultivated and uncultivated land, typically occurring in arid to semi-arid regions. As sand accumulations move, they can bury towns, roads, oases, crops, market gardens, irrigation channels, and dams, leading to significant material and socioeconomic damage (cf. FAO, 2010).

Reference

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Annotations

Synonyms

Sand dune migration. Sand invasion.

Additional scientific description

Sand accumulation forms vary depending on the landform, the type of surface they encroach upon, the presence or absence of vegetation, and the size of the sand grains (Hamdan et al., 2016). When the wind weakens, it loses its capacity to carry sand particles, causing them to be deposited (FAO, 2010).

Sand grain movement is controlled by:

- Avalanche effect: this is the result of saltation. As the grains of sand fall back, they displace more particles. The more intense the wind's saltation process, the greater the number of particles set in motion, until a saturation point is reached, where the quantity lost is equal to the quantity gained at any given moment. The distance needed to reach the saturation point depends on the sensitivity of a soil to erosion: on a very fragile soil, it can occur over a distance of about 50 m, but requires more than 1000 m on a very cohesive soil (FAO, 2010).
- Sorting - the sorting mechanism concerns the wind's displacement of the finest and lightest particles, leaving behind the larger particles. This process gradually impoverishes the soil, since the organic matter made up of small light elements is the first to be removed (FAO, 2010).
- Corrosion - corrosion is the mechanical attack on the surface as the sand-laden wind blows over it. In arid regions, it is the aggravating cause of soil erosion and is seen in parallel streaks or the polishing of rocks (FAO, 2010).

Metrics and numerical limits

The scale of sand encroachment depends on wind speed, which determines the sand removal force; the greater the speed, the higher the carrying capacity. Another key factor is the size and density of the sand particles. Sandy encroachments can vary from 50 cm in height, 150 cm in length and 40 cm in breadth, to 20 to 40 km long and 50 to 200 m wide (Al-Helal and Al-Awadhi, 2006). Sand encroachment reporting should indicate the accumulation location, scale, sand sources, and transport zones, as well as composition, topography and vegetation loss if known.

Key relevant UN conventions and multilateral treaties

Not applicable.

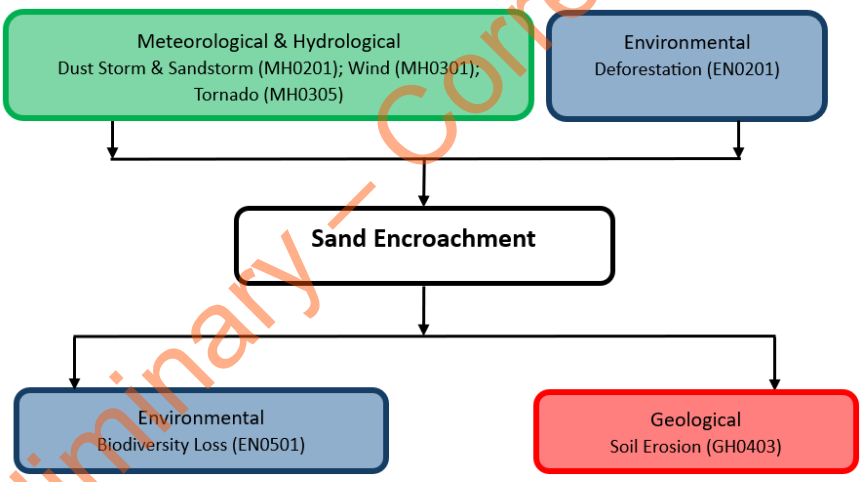
Examples of hazard drivers, impacts and risk management

Hazard Drivers: Several factors contribute to the formation and movement of sand masses. These include strong winds blowing across large areas, sparse or stunted vegetation, and degraded soil that is dry, bare, or prone to mobility (Khalaf and Al-ajmi, 1993; FAO, 2010).

Impacts: All forms of sand encroachment, regardless of size or duration, can create hazardous conditions, particularly affecting soil, vegetation, villages, roads (Boulghobra et al., 2015), railways, and irrigation channels:

- The wind first carries off the finer parts of the soil, thus weakening the soil structure. As the soil becomes sandier, it is more vulnerable to the wind and has a reduced water retention capacity. The terrain is gradually broken up by the creation of small mounds surrounding the woody and grassy vegetation as this degrades. The land gradually becomes unsuitable for cultivation (FAO, 2010).
  - The wind has both mechanical and physiological effects on vegetation. The mechanical effects occur as carried soil particles collide with stalks and leaves, abrading their tissue. In areas where particles are carried off, roots become exposed, and vegetation risks uprooting (FAO, 2010). Physiologically, the wind increases evaporation, drying out plants, particularly during the dry season in Kuwait. The wind's evaporative power is proportional to the square root of its speed. Moreover, the reduced water retention capacity of the soil leads to water stress. The surrounding or moving mass of dry air tends to absorb humidity and exacerbate water deficit and this deficit is the main factor determining local vegetation, inasmuch as the latter has to adapt to the severe shortage of water (Khalaf and Al-ajmi, 1993).

Multi-hazard Context: The figure below summarises common interactions between sand encroachment and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring sand encroachment. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Local authorities
How is the Hazard Monitored/Observed/Forecast?	Remote sensing images can be used to monitor sand encroachment

Risk Management: Risk management strategies are often localized and informal, for example removal of sand to clear roads. Larger scale management of dune systems involve using vegetation to stabilise sand dunes (UKCEH, 2021).

References

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Coordinating agency or organisation

Food and Agriculture Organization of the United Nations / British Geological Survey

Preliminary – Corrections Pending

GH0407 / GEOLOGICAL / Other Hazards

Ground Gases

Definition

Ground gases are natural gases generated by various processes including material decay (natural and anthropogenic) and magma bodies (adapted from UK HMRC, 2016 and USGS, no date).

References

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Preliminary – Corrections Pending

Annotations

Synonyms

Volcanic gases (GH0205), Magmatic gases, Landfill gas, Gas-contaminated land. Greenhouse gas. Marsh/swamp/bog gas.

Additional scientific description

Chemical or biological processes generate ground gases, for example, the breakdown of uranium-bearing minerals releasing radon from granite or by oxidation and or biogenic reduction (releasing hydrogen sulphide). In addition, naturally occurring ground gases are generated by the biogenic decay of organic matter, for example methane, carbon dioxide and phosphine gas.

The nitrogen cycle produces ammonium (NH^{+}_{4}), nitrous oxide (N_2O), nitric oxide (NO) or inorganic nitrogen gas (N_2). Nitrous oxide (N_2O) levels have risen in the atmosphere as a result of agricultural fertilization (also biomass burning, cattle and feed, and industrial sources).

Landfill gas is a product of the largely biogenic decomposition of anthropogenic waste. Its composition reflects that of the waste, but is dominated by methane and carbon dioxide, becoming more carbon dioxide rich as the waste ages, and with a small amount of non-methane organic compounds. Methane is a potent greenhouse gas (US EPA, no date).

Another source of ground gas associated with continental margins is methane hydrates (Geology.com, 2005-2020). Similarly, ground gases are emitted from volcanogenic sources. Volcanogenic gases escape from magma as a consequence of the pressure relief that occurs as the magma rises to the surface. These gases are also released via geothermal systems and fault systems activated by earthquakes. King et al. (2006) found elevated concentrations of soil gases such as carbon dioxide, helium, hydrogen, mercury vapour and radon in fault zones associated with earthquakes. These gases are released in combination with water vapour and particulate matter during volcanogenic events, or via fumaroles, and hydrothermal systems, as well as faults activated by earthquake events. Earthquakes can also trigger the release of soil gases derived from other sources.

Metrics and numerical limits

No globally agreed limits for ground gases; however, as an example, the UK limits for the following gases are:

- Methane is a colourless, odourless flammable gas. When the concentration of methane in air (oxygen 20.9% by volume [% v/v]) is

between the limits of 5% v/v and 15% v/v, an explosive mixture is formed. The Lower Explosive Limit (LEL) of methane is 5% v/v, which is equivalent to 100% LEL. The 15% v/v limit is known as the Upper Explosive Limit (UEL), but concentrations above this level cannot be assumed to represent safe concentrations, because of the potential for dilution to the UEL (NHBC, 2007). Methane is an important greenhouse gas, responsible for around 30% of the rise in global temperatures since the Industrial Revolution (IEA 2022). Methane has a global warming potential (GWP) of 29.8 ± 11 compared to CO_2 (potential of 1) over a 100-year period, and 82.5 ± 25.8 over a 20-year period.

- Carbon dioxide is a colourless, odourless gas, which, although non-flammable, is both a toxic gas and an asphyxiant. As carbon dioxide is denser than air, it will collect in low points and depressions, which can be an extreme hazard during foundation construction and earth movements on development sites. The Long-Term Exposure Limit (LTEL, 8-hour period) and the Short-Term Exposure Limit (STEL, 15-minute period) are 0.5% v/v and 1.5% v/v carbon dioxide, respectively (HSE, no date). The current global average concentration of carbon dioxide in the atmosphere is 425 ppm (March 2024). This is an increase of 50% since the start of the Industrial Revolution.
- Nitrous oxide, also known as laughing gas, it is a colourless non-flammable gas at room temperature. Atmospheric concentration is around 337 parts per billion (ppb) and is a major scavenger of stratospheric ozone, with an impact comparable to that of CFCs. About 40% of anthropogenic emissions are from agriculture.
- Radon is a colourless, odourless radioactive gas derived from the radioactive decay of radium, itself from the radioactive decay of uranium. The UK target level for homes is 100 Bq m3 (PHE, no date).
- Levels of hydrogen sulphide of 100 ppm and higher are considered immediately dangerous to life and health (NHBC, 2007).

For further details on metrics and numerical limits please refer to CH00xx Toxic Gases and CH00xx Asphyxiant Gases.

Key relevant UN conventions and multilateral treaties

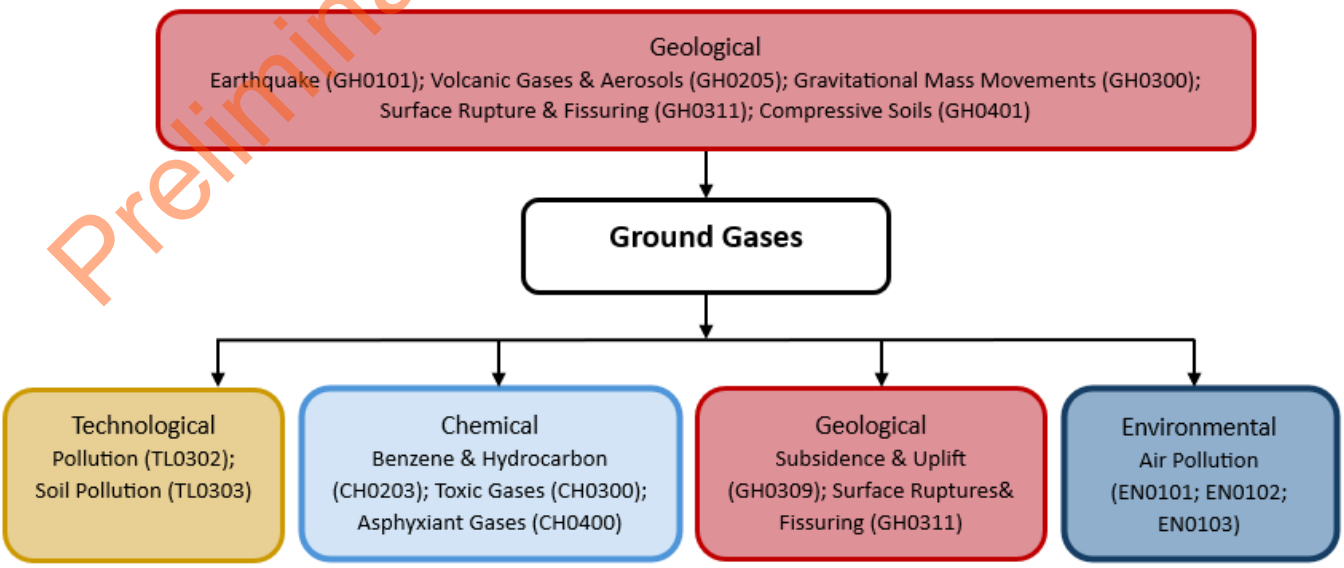
Not identified.

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Ground gases are generated through natural processes, and can be amplified by anthropogenic activity, such as waste management and agriculture. Volcanoes can produce abundant gas emissions. There are concerns about increasing methane emissions in the Arctic linked to the thawing of permafrost.

Impacts: Ground gases are a hazard in terms of risk to human health (see Asphyxiant Gases CH00xx and Toxic Gases CH00xx), flammability and climate change (greenhouse gases).

Multi-hazard Context: The figure below summarises common interactions between ground gases and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



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Monitoring: The section and the table below offer an overview of monitoring ground gases. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	No Information Available
How is the Hazard Observed/Monitored/Forecast?	Oxygen sensors, and similar devices for other gases, fitted with appropriate alarms can detect and warn of developing asphyxiant circumstances. Readers are referred to Toxic Gases (CH0300) for further information on early warning systems for ground gases.

Risk Management: Where possible, ground gas is monitored and controlled. Where buildings may come into contact with ground gases, specialist construction techniques are deployed to protect human health (e.g., NHBC, 2007). In the case of earthquake-triggered gases, consideration should also be given to the associated particulate matter. Signs in places that are prone to ground gases, for example along hiking trails can warn people of the hazard.

Landfill gas management has been a focal point for national-scale reductions in carbon dioxide emissions. For example, in 2018 waste management-related carbon dioxide formed 4.6% of UK carbon dioxide emissions (BEIS, 2020).

Ground gases occur in mining environments, for example in mining for coal (carbon dioxide, methane), potash (methane, nitrogen) and shale gas. In the UK, in these environments, control measures are guided by the Health and Safety Executive.

Readers are referred to Toxic Gases (CH00xx) and Asphyxiant Gases (CH00xx) for further information on drivers, impacts and risk management.

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Coordinating agency or organisation

British Geological Survey.

Preliminary - Corrections Pending

ENVIRONMENTAL

Preliminary – Corrections Pending

EN0101 / ENVIRONMENTAL / Environmental Degradation

Household Air Pollution

Definition

Definition Household air pollution is pollution primarily resulting from the incomplete combustion of solid fuels (e.g. wood, dung, charcoal, coal, kerosene), resulting in the emission of potentially toxic pollutants, including particles of varying sizes, carbon monoxide (CO), nitrogen dioxide, volatile and semi-volatile organic compounds (e.g. formaldehyde and benzo[a]pyrene), methylene chloride and dioxins. It is one of the leading environmental risk factors for disease and premature death and is generated by the use of inefficient and polluting fuels and technologies in and around homes.

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Reference

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Annotations

Synonyms

Indoor air pollution.

Additional scientific description

Around 2.4 billion people still cook using solid fuels (such as wood, crop wastes, charcoal, coal and dung) and kerosene in open fires and inefficient stoves (IEA, 2023). Most of these people are poor and live in low- and middle-income countries. These cooking practices are inefficient and utilise polluting fuels and technologies that produce high levels of household air pollution, containing a range of health-damaging pollutants, including small soot particles that penetrate deep into the lungs. In poorly ventilated dwellings, indoor smoke can be 100 times higher than acceptable levels for fine particles. Exposure is particularly high among women and young children, who spend the most time near the domestic hearth (WHO, 2018a)..

Exposure to smoke from cooking fires caused 3.3 million premature deaths per year in 2019 from illnesses attributable to household air pollution due to the use of inefficient and polluting fuels and technologies for cooking. Among these 3.3 million deaths: 23% were due to pneumonia; 22% from stroke; 31% from ischaemic heart disease; 18% from chronic obstructive pulmonary disease (COPD); and 6% from lung cancer (WHO, 2024).

The WHO provides definitions of clean, transitional and polluting fuels and technologies used for cooking, heating and lighting. For cooking, clean fuels and technologies are those that attain the fine particulate matter (PM2.5) and carbon monoxide (CO) levels recommended in the WHO global air quality guidelines (2021). The WHO Guidelines for indoor air quality: household fuel combustion (2014) provide PM2.5 and CO emission rate targets for devices, which are linked to the levels from the Air Quality Guidelines.

Metrics and numeric limits

Pollutant	Averaging time	Interim target				AQG level
		1	2	3	4	
$PM_{2.5}$, µg/m³	Annual	35	25	15	10	5
	24-hour[a]	75	50	37.5	25	15
PM_{10}, µg/m³	Annual	70	50	30	20	15
	24-hour[a]	150	100	75	50	45
O_3, µg/m³	Peak season[b]	100	70	–	–	60
	8-hour[a]	160	120	–	–	100
NO_2, µg/m³	Annual	40	30	20	–	10
	24-hour[a]	120	50	–	–	25
SO_2, µg/m³	24-hour[a]	125	50	–	–	40
CO, mg/m³	24-hour[a]	7	–	–	–	4

[a] 99th percentile (i.e. 3–4 exceedance days per year).
[b] Average of daily maximum 8-hour mean O_3 concentration in the six consecutive months with the highest six-month running-average O_3 concentration.

Table 1: Summary of recommended long- and short- term air quality levels in interim targets (WHO, 2021)

The WHO Air Quality Guidelines (WHO, 2021) offer recommended exposure levels for particulate matter (PM10 and PM2.5), ozone, nitrogen dioxide, sulphur dioxide and carbon monoxide, as well as a set of interim targets to encourage a progressive improvement in air quality, as outlined in Table 1 (WHO, 2021).

Key relevant UN convention/multilateral treaty

None identified.

Examples of hazard drivers, impact and risk management

Hazard drivers: Multiple factors contribute to household air quality degradation. Combustion processes, including residential heating, cooking and tobacco smoking, release a range of pollutants, such as carbon monoxide, nitrogen oxides and particulate matter, into indoor environments (Naeher et al., 2007). Building materials and furnishings emit volatile organic compounds (VOCs) and formaldehyde, further compromising indoor air quality (Harčárová et al., 2020). Biological contaminants, including mould, bacteria and allergens, can also proliferate within indoor spaces, particularly in environments with inadequate ventilation (Kumar et al., 2021).

The reliance on biomass fuels, which are the primary source of household air pollution in many countries, contributes to outdoor air pollution (Zuazua-Ros et al., 2023) and climate change. In some regions, fuel gathering for inefficient stoves contributes to environmental degradation, including deforestation and desertification (Martin et al., 2013). Moreover, household air pollution is often linked with energy poverty, where households lack access to clean energy sources. This limits economic opportunities and educational attainment, as children and adults are forced to allocate time to fuel collection instead of engaging in productive activities (Wang et al., 2022).

Impacts: Exposure to household air pollution has been linked to a variety of adverse health effects. Respiratory illnesses, including asthma and allergies, are commonly associated with poor indoor air quality. More severe health consequences, such as cardiovascular disease and cancer, have also been linked to long-term exposure (Lee et al., 2020). Additionally, household air pollution has been associated with reduced cognitive function, particularly in children (Wang et al., 2021).

Multi-hazard Context: The figure below summarises common interactions between household air pollution and other hazards. This information should be used with caution and not be solely relied upon in disaster risk management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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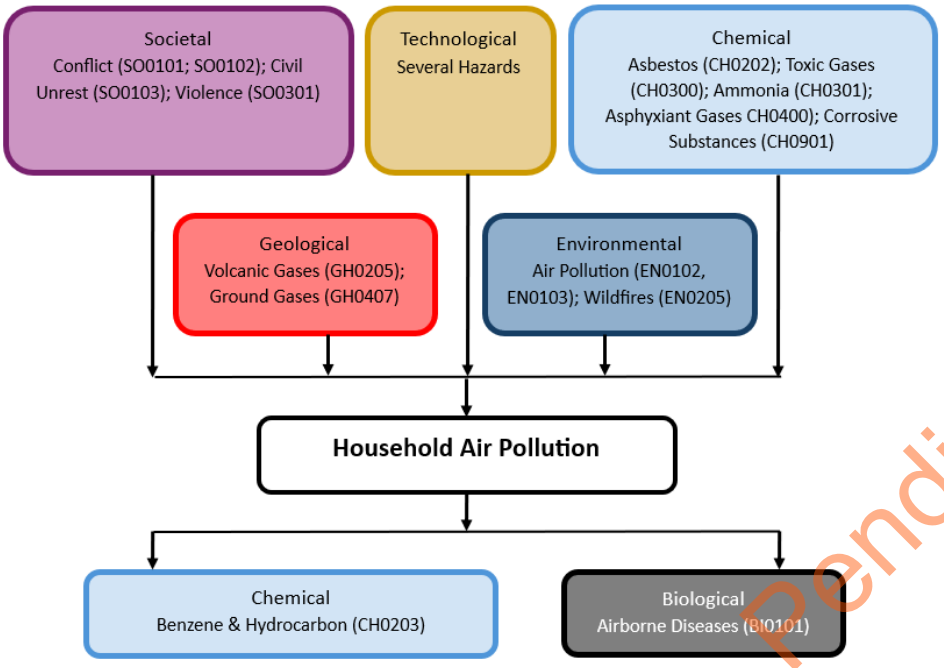

Monitoring: The section and the table below offer an overview of monitoring for household air pollution. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) disaster risk data/information?	Environmental agencies, health agencies.
How is the hazard observed/monitored/forecast?	Air quality sensors capable of detecting fine particulate matter (PM2.5) and volatile organic compounds (VOCs) within households (Kumar et al., 2021). These sensors provide continuous data, enabling the identification of pollution trends and acute exposure events (Chojer et al., 2024).

Risk Management: Mitigating the risks associated with household air pollution can be done through the use of effective ventilation and air filtration systems for diluting and removing pollutants from indoor spaces (Chojer et al., 2024). Source control measures, such as selecting low-emission building materials and furnishings, can significantly reduce indoor pollutant levels. Public awareness campaigns can empower individuals to adopt healthy indoor practices and reduce their exposure to household air pollution (Jung et al., 2023). Carbon finance incentives for clean stove adoption (IEA, 2023) can be an effective policy tool.

The WHO provides technical support to countries in their evaluations and scale-up of health-promoting household fuels and technologies (WHO, 2018a). This is further complemented by the development of the Clean Household Energy Solutions Toolkit (CHEST) to support the implementation of the WHO Guidelines for Indoor Air Quality: Household Fuel Combustion (WHO, 2014). CHEST provides a suite of tools and information resources that help countries identify stakeholders working on household energy and/or public health to design, implement and monitor policies addressing household energy (WHO, 2018a). The WHO also supports international initiatives to improve air pollution and related health impacts, such as the Clean Cooking Alliance and the Climate and Clean Air Coalition (WHO, 2018a).

Preliminary – Corrections Pending

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Coordination agency or organization

World Health Organization.

Preliminary – Corrections Pending

EN0102 / ENVIRONMENTAL / Environmental Degradation

Air Pollution (Point Source)

Definition

A point source of air pollution is an identifiable stationary location or fixed facility from which air pollutants are released, which may be human-made or natural in origin (adapted from Kibble and Harrison, 2005; Dunne et al., 2014).

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Annotations

Synonyms

Point source emissions, fugitive emissions, single-source emissions, stack emissions.

Additional scientific description

Point source air pollution focuses on acute and chronic sources of such pollution. It can be natural or human-made. A human-generated point source of air pollution emits a significant amount of air pollutants from a fixed location such as an explosion, pollutants from a chimney stack or a tyre fire, power stations, steel works, foundries, incinerators, wood and pulp processors, paper mills, refineries and chemical production (Kibble and Harrison, 2005; Dunne et al., 2014). Point sources of air pollution from naturally occurring sources include smoke from wildfires, ash from volcanic eruptions and sand particles from deserts lifted and transported in the wind across cities and continents in the form of sandstorms (Aghababaeian, 2021; Stewart, 2022; Paul et al., 2023).

Air pollutants can be emitted directly from a source (i.e. primary pollutants) or can form from chemical reactions in the atmosphere (i.e. secondary pollutants). When concentrations of these substances reach critical levels in the air, they harm humans, animals, plants and ecosystems, reduce visibility and corrode materials, buildings and cultural heritage sites (UNEP, no date).

In many cases, the key question is whether releases from a point source result in a significant increase in exposure or whether other sources (background exposure) give rise to the dominant exposure (Kibble and Harrison, 2005). Detailed investigation of these differences requires high spatiotemporal resolution air quality data alongside incidence data obtained from accurate health information systems, such as disease registers or via case-control studies.

Metrics and numeric limits

The WHO Air Quality Guidelines (WHO, 2021) offer recommended exposure levels for particulate matter (PM10 and PM2.5), ozone, nitrogen dioxide, sulphur dioxide and carbon monoxide, as well as a set of interim targets to encourage a progressive improvement in air quality, as outlined in Table 1 (WHO, 2021).

Pollutant	Averaging time	Interim target				AQG level
		1	2	3	4	
$PM_{2.5}$, μg/m³	Annual	35	25	15	10	5
	24-hour[a]	75	50	37.5	25	15
PM_{10}, μg/m³	Annual	70	50	30	20	15
	24-hour[a]	150	100	75	50	45
O_3, μg/m³	Peak season[b]	100	70	–	–	60
	8-hour[a]	160	120	–	–	100
NO_2, μg/m³	Annual	40	30	20	–	10
	24-hour[a]	120	50	–	–	25
SO_2, μg/m³	24-hour[a]	125	50	–	–	40
CO, mg/m³	24-hour[a]	7	–	–	–	4

[a] 99th percentile (i.e. 3–4 exceedance days per year).
[b] Average of daily maximum 8-hour mean O_3 concentration in the six consecutive months with the highest six-month running-average O_3 concentration.

Table 1: Summary of recommended long- and short- term air quality levels in interim targets (WHO, 2021)

Key relevant UN convention/multilateral treaty

In 1979, the UNECE Convention on Long-range Transboundary Air Pollution, was signed to deal with air pollution on a broad regional basis. The Convention entered into force in 1983, laying down the general principles of international cooperation for air pollution abatement and setting up an institutional framework which has since brought together research and policy. WHO International Health Regulations (WHO, 2016).

Examples of hazard drivers, impact and risk management

Hazard drivers: Point source air pollution, emanating from fixed locations, poses significant threats to human health and the environment. As outlined above, several factors contribute to point source air pollution, including industrial activities, power plants, transportation infrastructure such as airports and shipping ports, as well as the incineration of waste, particularly hazardous materials, that can release toxic air pollutants into the atmosphere. Incidents such as wildfires and volcanic eruptions can also impact air quality. For example, research shows that wildfires can cause a large increase in gaseous air pollutants such as carbon monoxide, nitrogen dioxide, acetaldehyde and formaldehyde (Finlay et al., 2012).

Although most emissions of point source air pollution are from local or regional sources, under certain atmospheric conditions air pollution can travel long distances across national borders over time scales of four to six days, thereby affecting people far from its original source. For example, windblown dust from desert regions of Africa, Mongolia, Central Asia and China can carry large concentrations of particulate matter, fungal spores and bacteria that impact health and air quality in remote areas. Therefore, global cooperation is needed to address international flows and sources of air pollutants, complementary to local and regional efforts in air pollution management (WHO, 2020).

Heatwaves or extreme temperatures can exacerbate ozone formation and intensify the impacts of pollutants on respiratory health.

Impacts: The impacts of point source air pollution are multifaceted. Exposure to air pollutants can lead to a range of health problems, including respiratory diseases, cardiovascular issues and increased risk of cancer. Vulnerable populations, such as children, the elderly and individuals with pre-existing conditions, are particularly susceptible (Kilian et al., 2018; Niu et al., 2022; Manisalidis, 2020). The WHO considers that all sources of air pollution contribute to early deaths; included in this are the combined effects of ambient (outdoor) and household air pollution, largely as a result of increased mortality from stroke, heart disease, chronic obstructive pulmonary disease, lung cancer and acute respiratory infections (Health Effects Institute, 2020; WHO, 2020). Adverse health consequences of air pollution can occur as a result of short- or long-term exposure. The pollutants with the strongest evidence of health effects are particulate matter, ozone, nitrogen dioxide and sulphur dioxide. Moreover, air pollution can harm ecosystems by acidifying lakes and rivers, damaging forests and contributing to climate change. Pollutants can also contaminate soil and water resources (Paerl, 1995).

Point sources emit a range of pollutants which can lead to both acute and chronic health effects in nearby populations (Kilian et al., 2018; Niu et al., 2022).

The environmental hazards associated with point source pollution are multifaceted. For instance, SO2 and NOx emissions contribute to the formation of acid rain, which can degrade ecosystems, harm aquatic life and damage vegetation and infrastructure

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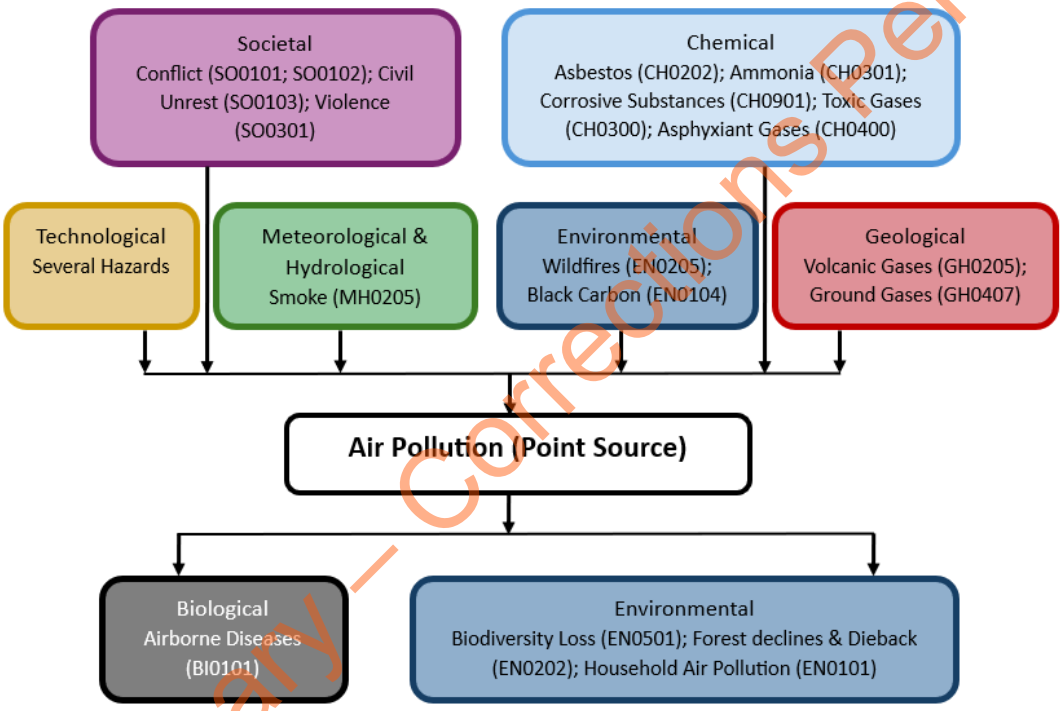
(Paerl, 1995). Additionally, these pollutants react with ground-level ozone and fine particulate matter, thereby damaging crops and forested areas, leading to reduced agricultural yields and biodiversity loss (Emberson, 2020; Ramanathan et al., 2009). Climate change introduces another layer of complexity, as higher temperatures can intensify the formation of secondary pollutants, such as ozone, and alter wind patterns, affecting the dispersion of emissions (Zanobetti et al., 2014).

Many people, particularly those in poorer populations or with pre-existing vulnerabilities, live near point sources of air pollution such as industrial sites and waste disposal operations. Point sources frequently generate speculation regarding potential associations with disease clusters such as cancer, among those living near the source location (Fairburn et al., 2019). However, there are currently limited epidemiological methods to enable effective detailed investigations into the impact of point-source air pollution and causal links with the disease of interest in identified clusters. There is a particular challenge with respect to obtaining reliable and accurate population exposure data at a very local level.

Multi-hazard Context: The figure below summarises common interactions between air pollution (point source) and other hazards. This information should be used with caution and not be solely relied upon in disaster risk management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring for air pollution. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) disaster risk data/information?	Environmental agencies, health agencies.
How is the hazard observed/monitored/forecast?	Network of air quality monitoring stations strategically placed across urban and industrial areas. These stations continuously measure concentrations of key pollutants, including PM2.5 and PM10, NO2, SO2, O3 and CO. Data from these sensors are transmitted in real-time to a central database, where they are analysed (Kelly et al., 2011).

Risk Management: To address the challenges posed by point source air pollution, effective risk management strategies are essential. Implementing stringent environmental regulations and standards can help control emissions from point sources. This includes setting limits on pollutant concentrations, requiring the use of cleaner technologies and conducting regular monitoring and inspections. Investing in research and development of cleaner technologies can reduce the environmental impact of industrial processes. This includes advancements in energy efficiency, pollution control equipment and alternative fuel sources. Additionally, implementing voluntary or mandatory emission reduction programmes can encourage industries to adopt more sustainable practices and reduce their environmental footprint.

Once an impending air quality deterioration is detected, the early warning system triggers alerts that are disseminated through

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various channels, including mobile apps, social media and traditional media outlets. These alerts are tailored to different audiences, providing specific recommendations for vulnerable groups, such as children, the elderly and individuals with pre-existing respiratory conditions. Public health advisories might include suggestions to reduce outdoor activities, close windows or use air purifiers. Moreover, the early warning system can guide policy responses, such as temporary traffic restrictions or industrial emissions controls, to mitigate the severity of pollution events (Kelly et al., 2011).

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Coordinating agency or organisation

World Health Organization

Preliminary – Corrections Pending

EN0103 / ENVIRONMENTAL / Environmental Degradation

Ambient (Outdoor) Air Pollution

Definition

Ambient (outdoor) air pollution is pollution that is present at concentrations that affect human health, ecosystems and agriculture. It is primarily measured through the presence of particulate matter (PM10 and PM2.5), ozone, nitrogen dioxide, sulphur dioxide and carbon monoxide in the air. Ambient air pollution is one of the leading environmental risk factors affecting urban and rural populations around the world, resulting in an estimated 4.2 million premature deaths in 2019 (WHO, 2024).

Preliminary – Corrections Pending

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WHO, 2024. Development Goal indicator 3.9.1: mortality attributed to air pollution. Geneva, World Health Organization, 2024. https://www.who.int/data/gho/data/themes/topics/indicator-groups/indicator-group-details/GHO/indicator-3.9.1-mortality-rate-attributed-to-household-and-ambient-air-pollution (Accessed 21 January 2025).

Annotations

Synonyms

Poor air quality, ambient air pollution, outdoor air pollution, polluted air.

Additional scientific description

Ambient (outdoor) air pollution is a major cause of death and disease globally. Long-term exposure (over years or lifetimes) reduces life expectancy, mainly due to cardiovascular and respiratory diseases and lung cancer. Short-term exposure (over hours or days) can also cause a range of health impacts, including effects on lung function, exacerbation of asthma, increases in respiratory and cardiovascular hospital admissions and mortality. Emerging evidence suggests links to dementia and cognitive decline, and effects on early life such as low birth weight (Kilian et al., 2018; Niu et al., 2022).

Ambient air pollution contains a range of pollutants from both natural (e.g. soil dust, salt spray, wildfire smoke) and man-made sources (e.g. energy, transport, industry, agriculture, inefficient combustion of fuels). Pollutants of major concern include PM, O3, NO2 and SO2 (WHO, 2020).

'Particulate matter' refers to a mixture of solid and liquid particles of varying size, shape and composition. Some particles are primary (emitted directly), others are secondary (formed through chemical reactions). Size and duration of exposure determine health risks. PM2.5 poses the greatest risk, penetrating deep into lungs and potentially entering the bloodstream (WHO, 2024a; PHE, 2019).

The effects of PM on health occur at levels of exposure currently being experienced by many people both in urban and rural areas and in developed and developing countries – although exposures in many fast-developing cities today are often far higher than in developed cities of comparable size. Reducing annual average fine particulate matter ($PM_{2.5}$) concentrations from current levels to the WHO guideline level of 5 µg/m^3, could reduce air pollution-related deaths by around 70%. However, even in the European Union, where PM concentrations in many cities do comply with guideline levels, it is estimated that average life expectancy is 8.6 months lower than it would otherwise be, due to PM exposures from human sources.

There are serious risks to health not only from exposure to PM, but also from exposure to O_3, NO_2 and SO_2. As with PM, concentrations are often highest largely in the urban areas of low- and middle-income countries.

Ozone at ground level – not to be confused with the ozone layer in the upper atmosphere – is one of the major constituents of photochemical smog. It is formed by the reaction with sunlight (photochemical reaction) of pollutants such as nitrogen oxides (NOx) from vehicle and industry emissions and volatile organic compounds (VOCs) emitted by vehicles, solvents and industry. As a result, the highest levels of O_3 pollution occur during periods of sunny weather. Excessive O_3 in the air can have a marked effect on human health. It can cause breathing problems, trigger asthma, reduce lung function and cause lung diseases.

As an air pollutant, NO_2 has several related impacts. Under short-term exposure to concentrations exceeding 200 µg/m^3, it is a toxic gas which causes significant inflammation of the airways. NO_2 is the main source of nitrate aerosols, which form an important fraction of $PM_{2.5}$ and, in the presence of ultraviolet light, of O_3. The major sources of anthropogenic emissions of NO_2 are combustion processes (heating, power generation, engines in vehicles and ships). Epidemiological studies have shown that symptoms of bronchitis in asthmatic children increase in association with long-term exposure to NO_2. Reduced lung function growth is also linked to NO_2 at concentrations currently measured (or observed) in cities of Europe and North America.

SO_2 is a colourless gas with a sharp odour. It is produced from the burning of fossil fuels (coal and oil) and the smelting of mineral ores that contain sulphur. The main anthropogenic source of SO_2 is the burning of sulphur-containing fossil fuels for domestic heating, power generation and motor vehicles. SO_2 can affect the respiratory system and lung function and can cause irritation of the eyes. Inflammation of the respiratory tract causes coughing, mucus secretion, aggravation of asthma and chronic bronchitis and makes people more prone to infections of the respiratory tract. Hospital admissions for cardiac disease and mortality, increase on days with higher SO_2 levels. When SO_2 combines with water, it forms sulphuric acid; this is the main component of acid rain which is a cause of deforestation.

Although air pollution can be harmful to everyone, some people are more affected because they live in a polluted area, are exposed to higher levels of air pollution in their daily lives or are more susceptible to health problems caused by air pollution. The most vulnerable face all of these disadvantages. Groups more affected by air pollution include older people, children, individuals with pre-existing cardiovascular or respiratory disease, pregnant women, communities in areas of higher air pollution and low-income communities (PHE, 2018).

It is also important to note that at present, there is no clear evidence of a safe level of exposure to air pollutants below which there is no risk of adverse health effects. Therefore, further reductions of concentrations of air pollutants below air quality standards are likely to bring additional health benefits. Actions that improve air pollution can also offer wider public health and wellbeing co-benefits.

Metrics and numeric limits

The WHO Air Quality guidelines (WHO, 2021) offer recommended exposure levels for particulate matter (PM_{10} and $PM_{2.5}$), O_3, NO_2, SO_2 and CO, as well as a set of interim targets to encourage a progressive improvement in air quality, as outlined in Table 1 (WHO, 2021).

Key relevant UN convention/multilateral treaty

In 1979, the UNECE Convention on Long-range Transboundary Air Pollution, was signed in 1979 to deal with air pollution on a broad regional basis. The Convention entered into force in 1983, laying down the general principles of international cooperation for air pollution abatement and setting up an institutional framework which has since brought together research and policy.

Pollutant	Averaging time	Interim target				AQG level
		1	2	3	4	
$PM_{2.5}$, µg/m³	Annual	35	25	15	10	5
	24-hour[a]	75	50	37.5	25	15
PM_{10}, µg/m³	Annual	70	50	30	20	15
	24-hour[a]	150	100	75	50	45
O_3, µg/m³	Peak season[b]	100	70	–	–	60
	8-hour[a]	160	120	–	–	100
NO_2, µg/m³	Annual	40	30	20	–	10
	24-hour[a]	120	50	–	–	25
SO_2, µg/m³	24-hour[a]	125	50	–	–	40
CO, mg/m³	24-hour[a]	7	–	–	–	4

[a] 99th percentile (i.e. 3–4 exceedance days per year).
[b] Average of daily maximum 8-hour mean O_3 concentration in the six consecutive months with the highest six-month running-average O_3 concentration.

Table 1: Summary of recomended long- and short- term air quality levels in interim targets (WHO, 2021)

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WHO International Health Regulations (WHO, 2016).

Examples of hazard drivers, impact and risk management

Hazard drivers: The primary drivers of ambient air pollution are diverse and often interlinked, encompassing both anthropogenic and natural sources. Industrial activities, particularly those involving the combustion of fossil fuels, are significant contributors. Power plants, manufacturing facilities and oil refineries release substantial quantities of pollutants such as SO_2, NO_x, PM and volatile organic compounds (VOCs) into the atmosphere (Kibble et al., 2005).

Transportation is another critical driver, with vehicles emitting a range of pollutants including CO, NO_x, PM and VOCs. The rapid urbanisation and economic growth witnessed in many low- and middle-income countries have led to increased vehicle ownership and congested traffic conditions, thereby amplifying urban air pollution levels. Additionally, the use of diesel engines, prevalent in freight and public transport, contributes significantly to fine particulate and black carbon emissions, which have profound health and climate implications (Colvile et al., 2001).

Agricultural practices also play a role. The burning of crop residues, commonly practised in several parts of the world to clear fields for planting, releases large amounts of PM and greenhouse gases. The use of fertilisers contributes to ammonia emissions, which can react in the atmosphere to form secondary particulate matter (Abdurrahman et al., 2020).

Natural sources, though often overlooked, contribute to background air pollution. Dust storms, wildfires and volcanic activity release substantial quantities of particulates and gases. However, the frequency and intensity of wildfires are increasingly influenced by human-induced climate change, creating a complex interplay between natural and anthropogenic drivers (Paul et al., 2023; Stewart, 2022; Aghababaeian, 2021).

Climatic factors such as temperature inversions–where a layer of warm air traps pollutants close to the ground–can lead to prolonged periods of high pollution levels (Trinh et al., 2019). This is compounded by increasing wildfire frequency and intensity, which release massive amounts of fine particulate matter and toxic gases, affecting air quality across vast regions (Paul et al., 2023).

Urbanisation and rapid industrialisation remain primary contributors to ambient air pollution. Pollutants originate from vehicular emissions, industrial processes, construction activities and the burning of fossil fuels (Kibble et al., 2005; Colvile et al., 2001). Urban heat islands–where elevated temperatures enhance ground-level ozone formation–exacerbate this pollution (Ulpiani, 2021).

Impacts: Ambient air pollution has wide-ranging impacts on human health, ecosystems and economies. Health-wise, exposure is linked to outcomes ranging from acute respiratory infections to chronic conditions such as asthma, cardiovascular disease and lung cancer. The World Health Organization estimates that ambient air pollution caused approximately 4.2 million premature deaths in 2019 (WHO, 2024b). Children, the elderly and individuals with pre-existing conditions are particularly vulnerable. Prenatal and early-life exposures have been associated with impaired lung development, reduced cognitive function and increased risk of chronic disease later in life (Kilian et al., 2018; Niu et al., 2022; Manisalidis, 2020).

Environmental impacts include ecosystem degradation through processes like acidification and eutrophication. Atmospheric deposition of nitrogen oxides (NO_x) from fossil fuel combustion contributes to nutrient enrichment in water bodies (Zhang et al., 2021). Ozone, a secondary pollutant formed through photochemical reactions involving NO_x and VOCs, damages crops and forests, leading to reduced yields and biodiversity loss (Emberson, 2020). Black carbon and methane are potent climate forcers, contributing to global warming (Ramanathan and Feng, 2009).

Economically, air pollution imposes significant burdens. Health-related costs–such as medical expenses and lost productivity–are substantial (Dechezleprêtre et al., 2019). Reduced crop yields affect food security, particularly in agrarian economies (Emberson, 2020). Pollution also deters tourism, degrades cultural heritage and increases urban cleaning and maintenance costs (Dechezleprêtre et al., 2019)

Multi-hazard Context: The figure below summarises common interactions between ambient (outdoor) air pollution and other hazards. This information should be used with caution and not be solely relied upon in disaster risk management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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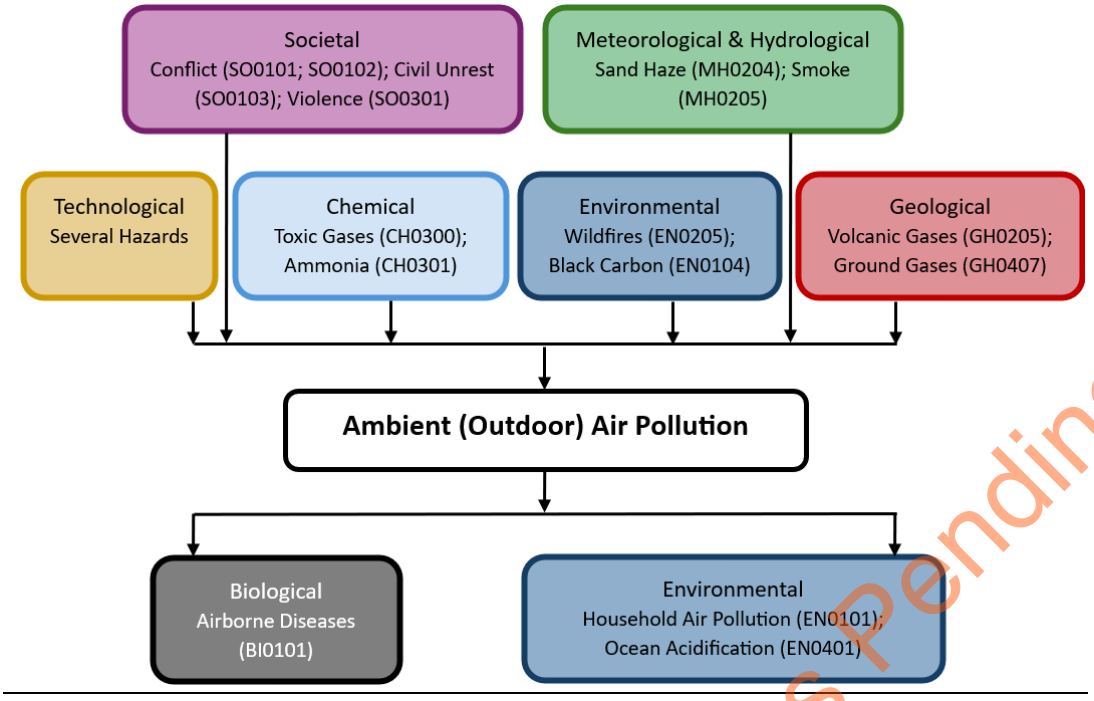

Monitoring: The section and the table below provide an overview of monitoring for ambient (outdoor) air pollution. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information should be obtained from the appropriate national or regional agency or authority responsible for disaster management.

Which institution(s) produce(s) disaster risk data/information?	Environmental agencies; health agencies
How is the hazard observed/monitored/forecast?	Country-specific networks of air quality monitoring stations are strategically placed in urban and industrial areas. These stations continuously measure concentrations of pollutants including $PM_{2.5}$, PM_{10}, NO_2, SO_2, O_3 and CO. Data from these sensors are transmitted in real time to central databases for analysis (Kelly et al., 2011). Satellite monitoring complements ground-based stations.

Risk Management: Most sources of outdoor air pollution are well beyond the control of individuals and their management requires concerted action by local, national and regional level policymakers working in sectors such as transport, energy, waste management, urban planning, and agriculture (WHO, 2024a). **Risk Management**: Most sources of outdoor air pollution are beyond the control of individuals. Effective management requires coordinated action at local, national and regional levels by policymakers in sectors such as transport, energy, waste management, urban planning and agriculture (WHO, 2024a). Successful examples include:

- *Industry:* Clean technologies to reduce smokestack emissions; improved waste management, including methane capture from landfills to produce biogas.
- *Energy:* Access to affordable, clean household energy for cooking, heating and lighting.
- *Transport:* Shifting to clean energy for power generation; prioritising urban public transport, walking and cycling networks; transitioning to low-emission and low-sulphur fuels and vehicles.
- *Urban planning:* Enhancing building energy efficiency and developing greener, more compact cities.
- *Power generation:* Increased use of low-emission fuels and renewable, combustion-free energy (solar, wind, hydropower); co-generation and distributed energy generation (e.g. mini-grids, rooftop solar).
- *Waste management:* Waste reduction, separation, recycling, reuse and biological processing (e.g. anaerobic digestion to produce biogas). Where incineration is necessary, emission-controlled combustion technologies are essential.

Once an impending air quality deterioration is detected, the early warning system triggers alerts that are disseminated through various channels, including mobile apps, social media and traditional media outlets. These alerts are tailored to different audiences, providing specific recommendations for vulnerable groups, such as children, the elderly and individuals with pre-existing respiratory conditions. Public health advisories might include suggestions to reduce outdoor activities, close windows or use air purifiers.

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Moreover, the early warning system can guide policy responses, such as temporary traffic restrictions or industrial emissions controls, to mitigate the severity of pollution events (Kelly et al., 2011).

- *Municipal and agricultural waste management:* strategies for waste reduction, waste separation, recycling and reuse or waste reprocessing; as well as improved methods of biological waste management such as anaerobic waste digestion to produce biogas, are feasible, low-cost alternatives to the open incineration of solid waste. Where incineration is unavoidable, then combustion technologies with strict emission controls are critical.

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Coordinating agency or organisation

World Health Organization, United nations Environment Programme.

Preliminary – Corrections Pending

EN0104 / ENVIRONMENTAL / Environmental Degradation

Black Carbon

Definition

Black carbon refers to the substance formed through the incomplete combustion of fossil fuels, biofuels and biomass, which is emitted in both anthropogenic and naturally occurring soot. It consists of pure carbon in several linked forms. Black carbon warms the Earth by absorbing heat in the atmosphere and by reducing albedo – the ability to reflect sunlight – when deposited on snow and ice. It is operationally defined as an aerosol species based on measurement of light absorption and chemical reactivity and/or thermal stability (UNEP, 2019).

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Annotations

Synonyms

Soot

Additional scientific description

Black carbon is a major component of $PM_{2.5}$. It is sometimes referred to as soot, and its main sources are the incomplete combustion of fossil fuels, biofuels and biomass. It can be emitted from both anthropogenic sources (e.g. diesel vehicles, biomass cookstoves) and natural sources (e.g. wildfires). It is also a potent warming agent in the atmosphere, contributing to regional environmental disruption and accelerating glacier melt. Short- and long-term exposure to black carbon has been associated with cardiovascular health effects and premature mortality (WHO, no date).

Black carbon is the sooty black material emitted from all forms of incomplete combustion of carbon-containing materials, including gas and diesel engines, coal-fired power plants and other fossil fuel-burning sources. It comprises a significant proportion of atmospheric particulate matter (PM), which is an air pollutant (US EPA, 2019).

Elevated black carbon concentrations in areas with high solar radiation are a major contributor to the so-called 'brown clouds' covering large regions, for instance in Asia. Black carbon plays a unique and important role in Earth's climate system (Bond et al., 2013), leading to dimming of the Earth's surface, warming of the atmosphere and perturbation of the hydrological cycle, possibly affecting the monsoon (WMO, 2009), and enhancing snowmelt in the cryosphere (Kang et al., 2020; Szopa et al., 2021).

Black carbon (BC), the second-largest contributor to global warming, has detrimental effects on human health and the environment. However, accurate quantification of BC remains a challenge, impeding comprehensive assessment of its impacts. Three quantitative methods are commonly used for measuring BC: thermal optical analysis (TOA), the optical method and laser-induced incandescence (LII) (Zhang et al., 2023).

Indoor black carbon is largely due to cooking, heating and lighting, with biofuels such as wood, dung and crop residue. Outdoor sources include fossil fuel combustion (diesel and coal), open biomass burning (linked to deforestation, crop residue burning and wildfires), waste burning and cooking with biofuels (Szopa et al., 2021).

Despite intensive efforts in recent decades, no widely accepted standard measurement method exists for determining black carbon or light-absorbing carbon. Real-time measurements can be performed using optical methods, which measure the absorption of light

through a filter collecting airborne particles (Ahmed et al., 2010).

Metrics and numeric limits

Not identified

Key relevant UN convention / multilateral treaty

UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP): Since 1979 the Convention on Long-range Transboundary Air Pollution has addressed some of the major environmental problems of the United Nations Economic Commission for Europe (UNECE) region through scientific collaboration and policy negotiation (UNECE, 1979). The Convention has been extended by eight protocols that identify specific measures to be taken by Parties to cut their emissions of air pollutants. The Convention, which now has 51 Parties, identifies the Executive Secretary of UNECE as its secretariat. In addition to this global convention, several national and regional agreements are also in place. (https://www.unep.org/interactives/air-pollution-note/).

The Climate and Clean Air Coalition (CCAC) is a voluntary partnership of over 190 governments, intergovernmental organisations, and non-governmental organisations founded in 2012, and convened within UNEP. Collectively and individually, partners who join the Climate and Clean Air Coalition are working to reduce powerful but short-lived climate pollutants (SLCPs) – methane, black carbon, hydrofluorocarbons (HFCs), and tropospheric ozone – that drive both climate change and air pollution. (https://www.ccacoalition.org/content/climate-and-clean-air-coalition).

The Clean Cooking Alliance (CCA) works with a global network of partners to build an inclusive industry that can make clean cooking accessible to all. Established in 2010, CCA is driving consumer demand, mobilising investment, and supporting policies that allow the clean cooking sector to thrive. (https://cleancooking.org/).

Arctic Council Fairbanks Declaration, 2017 (https://www.ccacoalition.org/resources/arctic-council-fairbanks-declaration).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Black carbon is formed by the incomplete combustion of fossil fuels, biomass and biofuels. Sources include: mobile sources, particularly diesel driven road vehicles, nonroad mobile machinery and ships; residential heating in combustion facilities, particularly burning of biomass such as fossil fuel coal and wood; and open biomass burning, forest fires and agricultural waste burning (EEA, 2013). Household waste burning is also a source of black carbon (Ramadan et al., 2023).

Impacts: Black carbon is a major component of $PM_{2.5}$ pollution, often making up 10-30% of measured $PM_{2.5}$ concentrations. As a harmful air pollutant, black carbon significantly contributes to the 4 million premature deaths from outdoor air pollution, the 3 million deaths from household air pollution and the trillions of dollars of economic cost (6% of global GDP) each year. There is growing evidence on the health impacts of exposure to black carbon specifically, which builds on a plethora of evidence on $PM_{2.5}$ more broadly. Assuming all components of $PM_{2.5}$ are equally toxic, outdoor/ambient black carbon exposure is estimated to be responsible for 150,000 excess deaths annually worldwide. Black carbon can also worsen extreme heat conditions and increase the risk of heatwave-related mortality. Black carbon has been linked to the increased temperature of heatwaves. Also, exposure to elevated levels of air pollution and black carbon has been shown to increase the risk of mortality from heatwaves. It is estimated that when particulate matter concentrations were high, heatwaves caused 36% and 106% more deaths in the 75-84 and 85+ age groups, respectively (Muduchuru et al., 2024). Full implementation of the reduction of black carbon emission in all Arctic Council member and observer states could reduce the annual global number of premature deaths by 329,000 by the year 2030, which amounts to 9% of the total global premature deaths due to particulate matter (Kühn et al., 2020).

Black carbon is a major contributor to the fine particulate ($PM_{2.5}$) burden in the air. It is small enough to be easily inhaled into the lungs and has been associated with adverse health effects. The Near-Road Exposures to Urban Air Pollutants Study (NEXUS) evaluated that peat-burning wildfires release enormous amounts of particulate matter, including black carbon, which has been linked to increased risk of heart failure and respiratory hospital visits (US EPA, 2019).

Black carbon emissions affect global warming, snow and ice melt, monsoon and weather patterns, flood risk, heat stress and public health. The potential benefits of reducing the emissions are felt most strongly close to the source. The dual nature of black carbon as a climate and air pollutant has resulted in neither of these fields taking full ownership. Therefore, black carbon remains largely absent from mainstream climate and health agendas (Muduchuru et al., 2024). More specifically, black carbon affects atmospheric radiative forcing through three distinct mechanisms: aerosol-radiation interactions, aerosol-cloud interactions, and snow darkening. Black carbon significantly influences regional surface temperatures, particularly in the Arctic, and has a substantial warming effect on the cryosphere, estimated to be approximately three times more potent than that of CO_2. Black carbon is also a significant contributor to regional precipitation changes and has been shown to drive the slowdown of the hydrological cycle, leading to drier conditions.

The darkening of snow through the deposition of black carbon and other light-absorbing particles enhances snowmelt. Sectors that emit large amounts of methane (agriculture and waste management) and black carbon (residential biofuel) are important contributors to warming over short time horizons of up to 20 years (Szopa et al., 2021).

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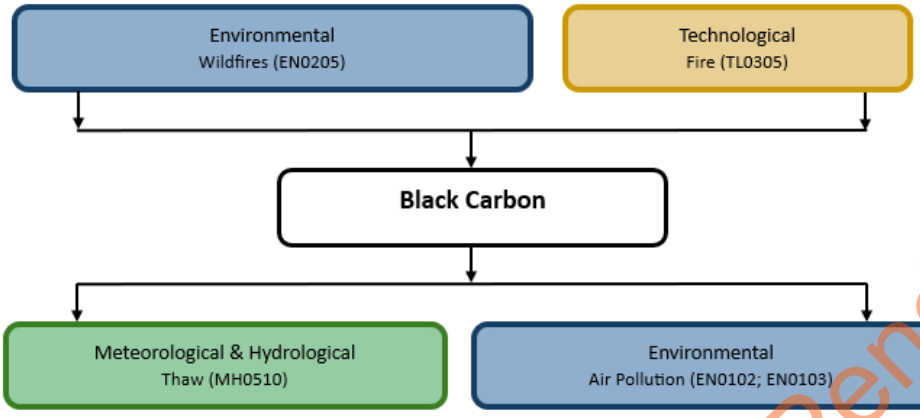
Multi-hazard Context: The figure below summarises common interactions between black carbon and other hazards. This information should be used with caution and not be solely relied upon in disaster risk management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: Air quality monitoring networks: the status of black carbon monitoring in Europe has been reported by the European Environment Agency (EEA, 2013).

Risk Management: Control measures: recommended measures include requiring regular vehicle emissions tests, retirement, or retrofitting; banning or regulating slash-and-burn clearing of forests and burning of agricultural waste; requiring shore-based electrification/power of ships, regulating idling at terminals, and mandating fuel standards for ships seeking to dock; banning or regulating the sale of certain fuels and/or requiring the use of cleaner fuels; requiring permits to operate industrial, power-generating and oil-refining facilities, and periodic permit renewal and/or modification of equipment; and requiring filtering technology and high-temperature combustion for existing power generation plants (EEA, 2013).

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Coordinating agency or organisation

World Meteorological Organization (WMO)

Preliminary – Corrections Pending

EN0105 / ENVIRONMENTAL / Environmental Degradation

Acid Rain

Definition

Acid rain is rain that, in the course of its history, has combined with chemical elements or pollutants in the atmosphere and reaches the Earth's surface as a weak acid solution (WMO/UNESCO, 2012).

Reference

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Preliminary – Corrections Pending

Annotations

Synonyms

Acid deposition, acid precipitation

Additional scientific description

Acids form when certain atmospheric gases come into contact with water in the atmosphere or on the ground and are chemically converted to acidic substances. Oxidants play a major role in several of these acid-forming processes. Carbon dioxide dissolved in rain is converted to a weak acid (carbonic acid). Other gases, primarily oxides of sulphur and nitrogen, are converted to strong acids (sulphuric and nitric acids). Rain is naturally slightly acidic owing to carbon dioxide, natural emissions of sulphur and nitrogen oxides, and certain organic acids; however, emissions from human activities can make it much more acidic. Occasional pH readings of well below 2.4 (the acidity of vinegar) have been reported in industrialised areas (US EPA, 2025a).

Acid rain can be formed by natural causes, such as volcanic eruptions. More commonly, however, acid rain is due to human activities (US EPA, 2025a). The main human sources are industrial and power-generating plants and transportation vehicles. Since the industrial revolution, emissions of sulphur and nitrogen oxides to the atmosphere have increased. Industrial and energy-generating facilities that burn fossil fuels, primarily coal, are the principal sources of increased sulphur oxide emissions (US EPA, 2025a).

Metrics and numeric limits

Normal rain has a pH of about 5.6, while the pH of acid rain is typically between 4.2 and 4.4. Acidity and alkalinity are measured using a pH scale, for which 7.0 is neutral. The lower the pH of a substance (below 7.0), the more acidic it is. The higher the pH of a substance (above 7.0), the more alkaline it is (US EPA, 2025a).

Key relevant UN convention / multilateral treaty

The Convention on Long-range Transboundary Air Pollution (LRTAP Convention) (UNECE, 1979) serves as an umbrella convention for the international regime on the regulation of transboundary acidification in the member states of the United Nations Economic Commission for Europe (UNECE). The USA and Canada are members of the UNECE, as are all European countries.

Since 1979, the LRTAP Convention has addressed some of the major environmental problems of the UNECE region through scientific collaboration and policy negotiation. The Convention has been extended by eight protocols that identify specific measures to be taken by Parties to cut their emissions of air pollutants. The Convention, which now has 51 Parties, identifies the Executive Secretary of the UNECE as its secretariat.

The 1986 U.S.-Canada Air Quality Agreement is a bilateral agreement aimed at addressing the transboundary air pollution that leads to acid rain (Government of Canada, 2021). The Ozone Annex was added to the Canada-United States Air Quality

Agreement (December 2000) to address the transboundary air pollution leading to high air quality levels of ground-level ozone, a major component of smog. The long-term goal of the Ozone Annex is the attainment of the ozone air quality standards in both countries. Where there are transboundary flows of pollution that create ozone, the Annex commits both countries to reduce their emissions of nitrogen oxides and volatile organic compounds, the precursor pollutants to ground-level ozone.

The 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (Gothenburg Protocol) was amended in 2012. The Protocol establishes national emission ceilings for four pollutants–sulphur (SO_2), nitrogen oxides (NO_x), volatile organic compounds (VOCs) and ammonia (NH_3)–covering the period from 2010 to 2020 (UNECE, no date).

Examples of hazard drivers, impacts, and risk management

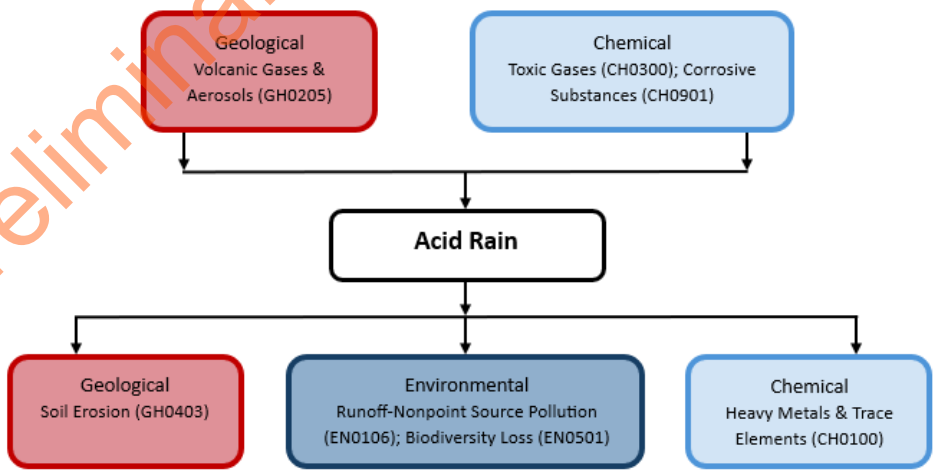
Hazard Drivers: Acid rain occurs when carbon dioxide (CO_2), sulphur dioxide (SO_2) and nitrogen oxides (NO_x) are emitted into the atmosphere and transported by wind and air currents. The CO_2, SO_2 and NO_x (see Chemical HIPs CH0300 and CH0901) carried in the air react with water, oxygen and other chemicals to form carbonic, sulphuric and nitric acids. These then mix with water and other materials before falling to the ground in the rain. While a small proportion of the SO_2 and NO_x that cause acid rain is from natural sources such as volcanoes, most are from the burning of fossil fuels to generate electricity. Sixty percent of SO_2 and 15% of the NO_x in the atmosphere are from electric power generation. Winds can transport SO_2 and NO_x over long distances and across national borders, making acid rain an international problem–for everyone, not just those living near the emission sources (US EPA, 2025a).

Impacts: Acid rain impacts both terrestrial and aquatic ecosystems, affecting the acidity of soils and water, which causes the leaching of metals into soil and water columns, further impacting biodiversity. In some areas, acid rain has resulted in fish deaths and loss of forests (US EPA, 2025b).

Plants are affected directly by acid rain due to reductions in growth, productivity and yield, by damaging photosynthetic mechanisms and reproductive organs, or indirectly by affecting underground components such as soil and root systems. Genes that play an important role in plant defence under abiotic stress are also modulated in response to acid rain. Acid rain induces soil acidification and disturbs the balance of carbon and nitrogen metabolism, litter properties, and microbial and enzymatic activities (Prakash et al., 2023).

Acid rain increases the acidity of lake water. This causes changes in the assemblages of plants and animals that occur naturally in the lake. An acid-stressed lake is typically very clear, with filamentous algae along the bottom and a reduced fish population. Acid rain can leach copper, aluminium and other heavy metals out of the soil and into runoff and drinking water. This process, in turn, puts more harmful materials in the water and soil, thus reducing the populations of organisms in the waterbody or soil. In some lakes, fish are unable to survive due to the acidity of the water (US EPA, 2025b).

Multi-hazard Context: The figure below summarises common interactions between acid rain and other hazards. This information should be used with caution and not be solely relied upon in disaster risk management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: NADP (USA) and EMEP (Europe) monitor acid rain via pH/ion concentration networks (NADP, 2024).

Risk Management: Addressing air pollution can reduce acid rain and its impacts. For example, the establishment of sulphur controls on power plants under the United States Acid Rain Program resulted in emissions reductions and subsequent mortality reduction (Barreca et al., 2021).

Preliminary – Corrections Pending

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Coordinating agency or organisation

World Meteorological Organization (WMO).

Preliminary – Corrections Pending

EN0106 / ENVIRONMENTAL / Environmental Degradation

Runoff / Nonpoint Source Pollution

Definition

Nonpoint sources of pollution refer to pollution that does not have a single point of origin or has not been introduced into a receiving freshwater or maritime environment from a specific outlet. The pollutants are generally carried off from the land by agricultural runoff, urban stormwater, atmospheric deposition or subaqueous groundwater discharges. The most common categories of nonpoint pollution are agriculture, forestry, urban areas, mining, construction, dams and channels, land disposal and saltwater intrusion.

Preliminary – Corrections Pending

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Annotations

Synonyms

Diffuse pollution

Additional scientific description

Nonpoint source pollution generally results from land runoff, precipitation, atmospheric deposition, drainage, seepage or hydrologic modification. Unlike pollution from industrial and sewage treatment plants, it originates from many diffuse sources. Runoff carries away natural and human-made pollutants, depositing them into lakes, rivers, wetlands, coastal waters and groundwaters (US EPA, 2020; NOAA, no date).

Nonpoint source pollution can include: excess fertilisers, herbicides and insecticides from agricultural lands and residential areas; oil, grease and toxic chemicals from urban runoff and energy production; sediment from improperly managed construction sites, crop and forest lands, and eroding streambanks; salt from irrigation practices and acid drainage from abandoned mines; bacteria and nutrients from livestock, pet wastes and faulty septic systems; and atmospheric deposition and hydromodification (US EPA, 2020).

Metrics and numeric limits

Not identified.

Key relevant UN convention/multilateral treaty

While there are no UN conventions or multilateral treaties that specifically address nonpoint source pollution, there are some that focus on point source pollution that may have some relevance when considering nonpoint source pollution, as outlined below.

The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (IMO, 1972), the 'London

Convention', is one of the first global conventions to protect the marine environment from human activities and has been in force since 1975. Its objective is to promote the effective control of all sources of marine pollution and to take all practicable steps to prevent pollution of the sea by dumping of wastes and other matter.

The International Convention for the Prevention of Pollution from Ships (MARPOL) 1996 (IMO, 1996) is the main international convention covering the prevention of pollution of the marine environment by ships from operational or accidental causes. The MARPOL Convention was adopted on 2 November 1973. The Protocol of 1978 was adopted in response to a spate of tanker accidents in 1976-1977. As the 1973 MARPOL Convention had not yet entered into force, the 1978 MARPOL Protocol absorbed the parent Convention. The combined instrument entered into force on 2 October 1983. In 1997, a Protocol was adopted to amend the Convention and a new Annex VI was added, which entered into force on 19 May 2005. MARPOL has been updated by amendments through the years to the London Convention (the 'London Protocol').

The UNECE Convention on Long-range Transboundary Air Pollution was the first international treaty to deal with air pollution on a broad regional basis. The Convention entered into force in 1983, laying down the general principles of international cooperation for air pollution abatement and setting up an institutional framework which has since brought together research and policy. Over the years, the number of substances covered by the Convention and its protocols has been gradually extended, notably to ground-level ozone, persistent organic pollutants, heavy metals and particulate matter.

Examples of hazard drivers, impacts and risk management

Hazard drivers: Nonpoint source pollution, originating from diffuse sources rather than a single identifiable point, poses a significant threat to water quality and ecosystem health. Several anthropogenic activities contribute to nonpoint source pollution. Land-use practices, including agriculture, forestry and urbanisation, are primary drivers (Müller et al., 2020). Agricultural activities, such as the application of fertilisers and pesticides (see Pesticides CH0501 and Ammonium Nitrate CH0902 HIPs), are major sources of nutrient and chemical contamination (Xia et al., 2020). Deforestation and land clearing associated with urbanisation and development can increase soil erosion, leading to elevated sediment loads in waterways (Benavides et al., 2005). Additionally, climate change, through altered precipitation patterns and increased frequency of extreme weather events, can exacerbate nonpoint source pollution by enhancing runoff and erosion processes (Sharma et al., 2016; Ahmed et al., 2016).

The primary concern associated with nonpoint source pollution lies in its degradation of water quality. Pollutants like fertilisers, pesticides, sediment and pathogens carried by runoff contaminate freshwater and marine environments. This contamination disrupts vital ecological processes, reduces biodiversity, and diminishes the suitability of water bodies for various uses, including drinking water, recreation and fisheries. Furthermore, excess nutrients from nonpoint source pollution can trigger the proliferation of harmful algal blooms. These blooms deplete oxygen levels in water bodies upon decomposition, creating hypoxic zones where aquatic life struggles to survive (Pericherla et al., 2020). Additionally, deforestation and land-use changes associated with nonpoint source pollution can alter drainage patterns and increase soil erosion, leading to increased sediment loads in waterways and a higher risk of landslides and floods (Benavides et al., 2005).

Climate change is projected to alter precipitation patterns, potentially leading to increased runoff events and exacerbating nonpoint source pollution. Similarly, extreme weather events like hurricanes and floods can further exacerbate erosion and pollutant mobilisation. Conversely, land degradation processes like desertification and overgrazing can leave soil more susceptible to erosion, further intensifying nonpoint source pollution (Bolan et al., 2023). The consequences of this multi-hazard context are far-reaching. Public health risks arise from exposure to pathogens and harmful chemicals in contaminated water sources (Ahmed et al., 2019). Degraded water quality can also negatively impact fisheries and tourism industries, affecting livelihoods and economic stability in affected regions. Food security can also be threatened by disruptions to fish populations due to harmful algal blooms and dead zones (McCarthy et al., 2008). Moreover, the combined effects of nonpoint source pollution and other environmental hazards can strain freshwater resources, making clean water a scarce commodity in some areas.

Impacts: The consequences of nonpoint source pollution are far-reaching. Water quality degradation, characterised by elevated nutrient levels, increased turbidity and contamination by pathogens, is a primary impact. Eutrophication, resulting from nutrient enrichment, can lead to harmful algal blooms, hypoxia and anoxia, disrupting aquatic ecosystems (Pericherla et al., 2020). Sedimentation can smother benthic habitats, impair aquatic organism reproduction and reduce water clarity. Furthermore, nonpoint source pollution can pose human health risks through exposure to contaminated water, with implications for recreation, drinking water supply and fisheries (Wu et al., 2013; Xepapadeas, 2011).

Multi-hazard Context: The figure below summarises common interactions between runoff/nonpoint source pollution and other hazards. This information should be used with caution and not be solely relied upon in disaster risk management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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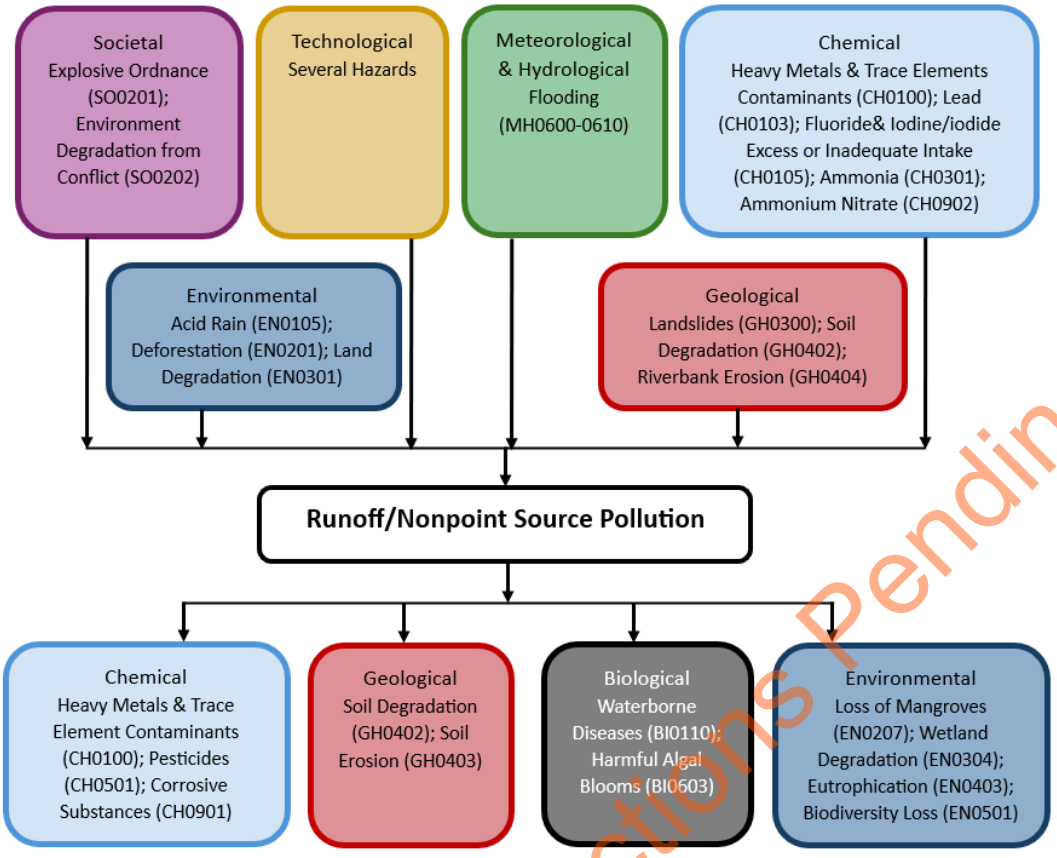

Monitoring: The section above and the table below offer an overview of monitoring for runoff/nonpoint source pollution. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) disaster risk data/information?	Environmental agencies, water agencies, health agencies
How is the hazard observed/monitored/forecast?	General monitoring of common pollution sources, water and air quality. Deploying sensors in rivers, streams and lakes to measure turbidity, nitrate levels and dissolved oxygen provides continuous data on water body health. Sudden spikes in these parameters can indicate potential nonpoint source pollution events. Satellite imagery can track land cover changes, identifying areas prone to erosion and runoff. Additionally, monitoring soil moisture levels can provide insights into potential pollutant transport. Weather forecasts, particularly those predicting heavy rainfall or extreme weather events, are crucial, as these conditions can significantly increase nonpoint source pollution risks. Ground-level observations are equally important. Citizen science programmes, engaging local communities in water quality monitoring, can provide valuable data on localised pollution events. Visual observations of water clarity, algal blooms or increased erosion can serve as early indicators (Munafò et al., 2005).

Risk Management: Effective management of nonpoint source pollution requires a multi-faceted approach. Implementing best management practices in agriculture, forestry and urban areas is crucial for reducing pollutant loads. This includes practices such as cover cropping, conservation tillage and riparian buffers (Barber et al., 2012). Land-use planning and zoning regulations can also help mitigate nonpoint source pollution by minimising development in sensitive areas (Revitt et al., 2014; Ioannidou et al., 2020).

Given the diffuse nature of nonpoint source pollution, it can be difficult to develop early warning systems that specifically target their sources and impacts.

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Preliminary – Corrections Pending

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Coordinating agency or organisation

United Nations Environment Programme

Preliminary – Corrections Pending

EN0201 / ENVIRONMENTAL / Environmental Degradation (Forestry)

Deforestation

Definition

Deforestation is the conversion of forest to other land use independently of whether human-induced or not (FAO, 2023).

Reference

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Preliminary – Corrections Pending

Annotations

Synonyms

Loss of forest cover, forest loss, forest clearance

Additional scientific description

The Food and Agriculture Organization of the United Nations (FAO) has monitored the world's forests at 5- to 10-year intervals since 1946. The recent Global Forest Resources Assessments have been produced every five years in an attempt to provide a consistent approach to describing the world's forests and how they are changing (FAO, 2020).

Deforestation includes the permanent reduction of the tree canopy cover below the minimum 10% threshold. It also includes areas of forest converted to agriculture, pasture, water reservoirs, mining, other infrastructure and urban areas. The term specifically excludes areas where the trees have been removed as a result of harvesting or logging, and where the forest is expected to regenerate naturally or with the aid of silvicultural measures. The term also includes areas where, for example, the impact of disturbance, over-utilisation or changing environmental conditions affects the forest to an extent that it cannot sustain a canopy cover above the 10% threshold (FAO, 2023).

Deforestation and forest degradation continue to take place at alarming rates and contribute significantly to the ongoing loss of biodiversity (FAO and UNEP, 2020). Since 1990, it is estimated that 420 million hectares of forest have been lost through conversion to other land uses, although the rate of deforestation has decreased over the past three decades (FAO, 2020a).

Between 2015 and 2020, the rate of deforestation was estimated at 10 million hectares per year, down from 16 million hectares per year in the 1990s. The area of primary forest worldwide has decreased by over 80 million hectares since 1990 (FAO, 2020).

Agricultural expansion continues to be the main driver of deforestation and forest degradation and the associated loss of forest biodiversity. Large-scale commercial agriculture (primarily cattle ranching and cultivation of soya bean and oil palm) accounted for 40% of tropical deforestation between 2000 and 2010, and local subsistence agriculture for another 33% (FAO & UNEP, 2020).

Metrics and numeric limits

Deforestation area expressed in thousand hectares per year for the following periods: 1990-2000, 2000-2010, 2010-2015 and 2015-2020 (FAO, 2020).

The data for the Global Forest Resources Assessment are collected using an online tool that also serves as a data dissemination platform. All data countries and territories reported to Global Forest Resources Assessment 2020 are available at https://fra-data.fao.org (FAO, no date).

Key relevant UN convention/multilateral treaty

Convention on Biological Diversity (CBD): Established in 1992 and entered into force on 29 December 1993, the convention has three main objectives: the conservation of biological diversity; the sustainable use of the components of biological diversity; and the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources (CBD, 1992).

United Nations Framework Convention on Climate Change (UNFCCC): Negotiated from February 1991 to May 1992, the Convention entered into force on 21 March 1994. It seeks to reduce atmospheric concentrations of greenhouse gases, with the aim of preventing dangerous anthropogenic interference with the Earth's climate system. At the Conference of the Parties (COP21) in Paris, on 12 December 2015, Parties to the UNFCCC reached a landmark agreement to combat climate change and to accelerate and intensify the actions and investments needed for a sustainable low-carbon future (UNFCCC, 2015).

United Nations Convention to Combat Desertification (UNCCD): Established in 1994, this Convention is the sole legally binding international agreement linking environment and development to sustainable land management. The Convention addresses specifically the arid, semi-arid and dry sub-humid areas, known as the drylands, where some of the most vulnerable ecosystems and peoples can be found (UNCCD, 2017).

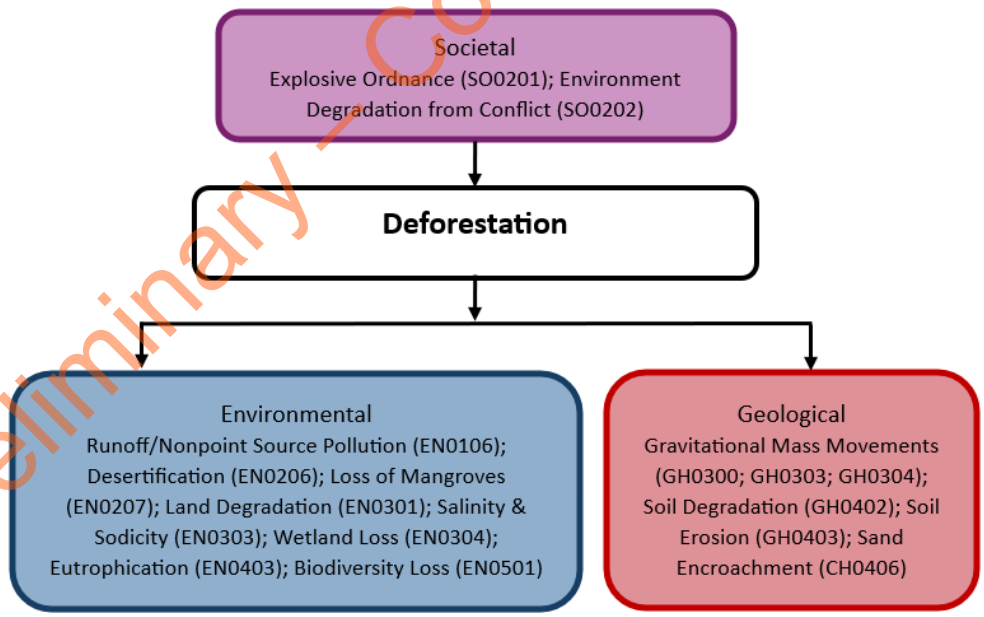
The United Nations Strategic Plan for Forests 2017-2030: Launched in 2017, this strategy provides a global framework for action for sustainable forest management, and to end deforestation and forest degradation. It encompasses a set of six Global Forest Goals and 26 associated targets to be voluntarily achieved by 2030. Among others, it includes a target to increase forest area by 3% worldwide by 2030, which translates into an increase of 120 million hectares (United Nations, 2017).

Examples of hazard drivers, impact and risk management

Hazard Drivers: Agricultural expansion is the main driver of deforestation and forest fragmentation and the associated loss of forest biodiversity.

Impacts: In the tropical domain, the net annual loss of forest area from 2000 to 2010 was about 7 million hectares, and the net annual increase in agricultural land area was more than 6 million hectares. There were significant regional variations: Central and South America, sub-Saharan Africa, and South and Southeast Asia all had net losses of forest and net gains in agricultural land (FAO & UNEP, 2020). Small-scale farming was the main global driver of the majority of the converted forest to cropland and grassland during the 2000-2018 period, which amounted to 68% of all agriculture-driven deforestation–40% for cropland and 28% for livestock grazing (Branthomme et al., 2023).

Multi-hazard Context: The figure below summarises common interactions between deforestation and other hazards. This information should be used with caution and not be solely relied upon in disaster risk management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above..



Preliminary – Corrections Pending

Monitoring: The section and the table below offer an overview of monitoring for deforestation. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) disaster risk data/information?	Ministry of Forestry, Ministry of Environment, Ministry of Agriculture, Ministry of Planning – depending on jurisdiction See Colombia's example here: https://repositorio.gestiondelriesgo.gov.co:8443/handle/20.500.11762/32753?show=full

How is the hazard observed/monitored/forecast?	Monitored via systematically acquired satellite imagery (e.g. Landsat, Copernicus programme data).

Risk Management: Creation of protected areas has historically been the forest governance instrument most often adopted to pursue biodiversity protection objectives. This approach has achieved positive results in terms of conserving species and establishing barriers to the progress of deforestation (FAO & UNEP, 2020).

It is considered that agribusinesses should meet their commitments to deforestation-free commodity chains, and those companies that have not made zero-deforestation commitments should do so. Commodity investors should adopt business models that are environmentally and socially responsible. These actions will, in many cases, require a revision of current policies and financial incentives (FAO & UNEP, 2020).

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Coordinating agency or organisation

Food and Agriculture Organization of the United Nations (FAO).

Preliminary – Corrections Pending

EN0202 / ENVIRONMENTAL / Environmental Degradation

Forest Declines and Diebacks

Definition

Forest declines and diebacks are episodic events characterised by premature, progressive loss of tree and stand vigour and health over a given period without obvious evidence of a single clearly identifiable causal factor such as physical disturbance or attack by primary disease or insect (Ciesla & Donaubauer, 1994).

Tree declines can be described as the gradual deterioration of plant tissues over time, triggered by a series of adverse events such as abiotic stress, climate deregulation, the emergence of new pathogens, biological invasions and agricultural strategies. Declines may also be seen as a long-term reduction of wood or fruit productivity, leading (or not) to sudden tree mortality, occasionally referred to as dieback (Bettenfeld et al., 2020).

Reference

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Preliminary – Corrections Pending

Annotations

Synonyms

Stand-level dieback, canopy-level dieback, Walsterben, Waldschaden

Additional scientific description

Forest decline is characterised by the presence of symptoms such as reduced growth, shortened internodes, root necrosis, premature fall colouring in temperate forests, yellowing and loss of foliage, dieback of twigs and branches generally beginning in the upper crown, sprouting from adventitious buds, and/or increased prevalence and pathogenicity of root decay fungi (Manion & Lachance, 1992).

The decline has been considered a symptom of disease, a distinct class of disease, and as part of forest dynamics. Another widely accepted concept describes decline as a result of the interaction of predisposing, inciting and contributing factors (Manion & Lachance, 1992). Predisposing factors are often of long-term duration with slowly changing factors such as soil, site and climate. These factors alter the ability of trees to withstand or respond to injury-inducing agents.

Compared with less complex or non-multifactorial diseases, it is difficult to define a state of decline just by looking at its symptoms, since these can vary widely depending on the species or individual tree. Because they result from multiple factors working together, it is difficult to link specific symptoms to a single cause. In most cases, the entire tree is affected over time, with damage spreading from one part to another, eventually impacting its overall health. This can lead to visible signs such as major biomass

loss, as seen in poplar and ash, or a reduction in fruit quality and quantity, as in grapevines and olive trees (Bettenfeld et al., 2020).

Metrics and numeric limits

The Food and Agriculture Organization of the United Nations (FAO) has been monitoring the world's forests at 5- to 10-year intervals since 1946. FAO's Global Forest Resources Assessments (FRA) have been produced every five years in an attempt to provide a consistent approach to describing the world's forests and how they are changing.

The guidelines and specifications for FAO's FRAs have been adapted both in scope and reporting regularity to better respond to recent developments in the international forest policy arena, such as the United Nations' 2030 Agenda for Sustainable Development, the United Nations Strategic Plan for Forests 2017-2030, and the 2015 Paris Agreement. Furthermore, the reporting content has been streamlined, and a new online reporting platform has been developed to make reporting more efficient and to decrease countries' reporting burden (FAO & UNEP, 2020).

Key relevant UN convention/multilateral treaty

UN Climate Change Convention: At the Conference of the Parties (COP21) in Paris, on 12 December 2015, Parties to the United Nations Framework Convention on Climate Change (UNFCCC) reached a landmark agreement to combat climate change and to accelerate and intensify the actions and investments needed for a sustainable low-carbon future.

Examples of hazard drivers, impacts, and risk management

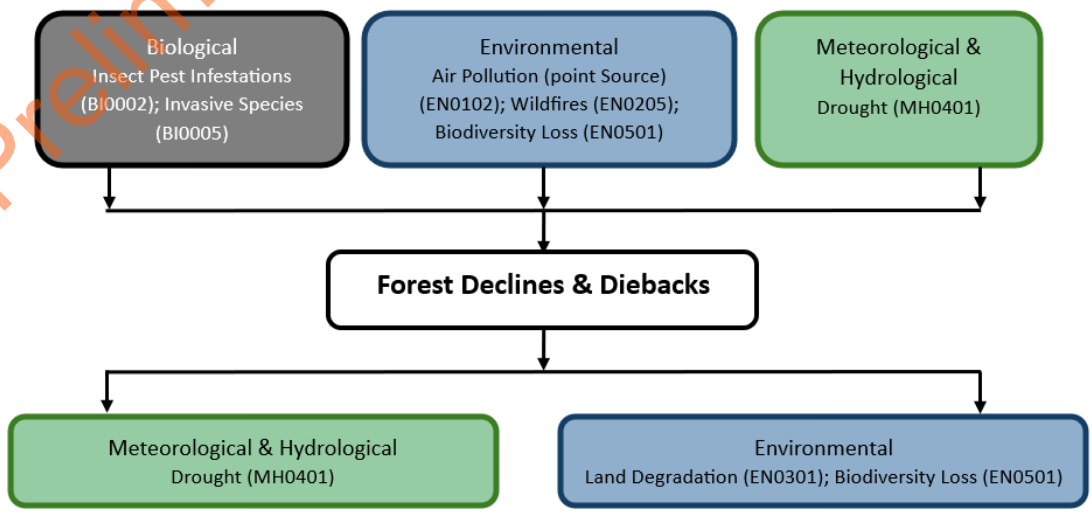
Drivers: Multiple factors such as insect pest and disease outbreaks (Morand & Lajaunie, 2021), and extreme weather events such as drought, are considered the main causes of forest decline and diebacks. However, human activities such as pollution, urbanisation and encroachments on sensitive habitats can exacerbate what would ordinarily be cyclical occurrences of these factors. Forest decline can be hastened and worsened as the forest ecosystem becomes less resilient and more sensitive to changes, whether natural or anthropogenic (Martínez-Vilalta et al., 2012; DeSantis et al., 2016; Morand & Lajaunie, 2021).

Forest declines and diebacks result from complex interactions between multiple hazards, both biotic and abiotic, which can be further intensified by anthropogenic stressors. Abiotic stressors include drought, water deficiency, soil degradation, pollution, storms, fires, heatwaves, frost and late snow events. Biotic stressors include invasive insect pests, plants, pathogens and mammals.

Impacts: The complexity of declines and diebacks makes it challenging to quantify their impact, and as a result, available data remain limited and require further development.

Forest dieback has far-reaching impacts beyond the loss of trees. It disrupts the intricate web of ecological relationships within forests, affecting wildlife populations, soil fertility, water cycles and the livelihoods of communities that depend on forest resources (UNU-EHS, 2023).

Multi-hazard Context: The figure below summarises common interactions between forest declines and diebacks and other hazards. This information should be used with caution and not be solely relied upon in disaster risk management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring for forest declines and diebacks. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the

Preliminary – Corrections Pending

most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) disaster risk data/information?	National forest agencies
How is the hazard observed/monitored/forecast?	Ground surveys and remote sensing. The Global Forest Watch is an online platform that provides data and tools for monitoring forests. https://www.globalforestwatch.org/about/

Risk Management: Risk management includes sustainable forest management to establish resilient forest ecosystems, establish early warning and early action systems for pests and diseases, and increase community participation in forest management.

Early warning systems (EWS) for forest decline and dieback rely on detecting subtle signs of ecosystem stress before significant damage occurs. Forests are exposed to various pressures, including climate change, pests, pollution and human disturbances, which can trigger forest declines (Dong & Fang, 2024).

Physiological changes, such as shorter growing periods, reduced carbon and water-use efficiency, and hydraulic failure, often precede visible decline. Researchers use statistical methods such as lag-1 autocorrelation and spatial analysis to identify critical slowing down, which signals reduced ecosystem recovery capacity and potential tipping points. Remote sensing, particularly NDVI monitoring, helps track vegetation health over time, offering a robust tool for early detection (Alibakhshi, 2023; Dong & Fang, 2024).

However, challenges remain in refining these methodologies to reduce false alarms and improve real-world applications. Advances in remote sensing and spatial-temporal analysis are enhancing the accuracy of EWS, making them essential for proactive forest management.

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Coordinating agency or organisation

Food and Agricultural Organization of the United Nations (FAO).

Preliminary – Corrections Pending

EN0203 / ENVIRONMENTAL / Environmental Degradation

Forest Disturbances

Definition

Forest disturbance is the damage caused by any factor (biotic or abiotic) that adversely affects the vigour and productivity of the forest, and which is not a direct result of human activities. It includes disturbance by insect pests, diseases, severe weather events and fires (FAO, 2018; 2020).

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Preliminary – Corrections Pending

Annotations

Synonyms

None identified.

Additional scientific description

Forest area is defined by the Food and Agriculture Organization of the United Nations (FAO) as: land spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of more than 10%, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use (FAO, 2018).

The world's total forest area is approximately 4.06 billion ha, which is 31% of the total land area. This area is equivalent to 0.52 ha per person. Forests are not distributed equally among the world's people or geographically. The tropical domain has 45% of the world's forests. It should also be noted that more than half (54%) of the world's forests are in only five countries: the Russian Federation, Brazil, Canada, the United States of America and China (FAO, 2020).

Forest disturbances include areas of forest affected by:

(i) Insects – disturbance caused by insect pests;

(ii) Diseases – disturbance caused by pathogens, such as bacteria, fungi, phytoplasma or viruses;

(iii) Severe weather events – disturbance caused by abiotic factors, such as snow, storms, droughts, etc.;

(iv) Fire – forest area affected by fire (FAO, 2018).

Forest degradation does not have a single commonly agreed definition but is considered to occur when forest ecosystems lose their capacity to provide important goods and services to people and nature (IUCN, 2017).

Measuring forest degradation and disturbance is challenging. There is no commonly agreed definition or monitoring method. Degradation and disturbances can entail long-term negative changes in the structure, composition and other characteristics of the forest which can be difficult to detect.

Metrics and numeric limits

The *Global Forest Resources Assessment 2020* noted that relatively few data were available for forest disturbance and that it was not possible to estimate accurately the total forest area affected by disturbances globally (FAO, 2020). Only 36 countries and territories, accounting for just 25% of the world's forest area, reported complete time-series data for the forest area

disturbed annually by insects (2000-2017). Therefore, further discussion is warranted on how best to obtain and analyse data and whether more information is needed to properly assess forest disturbance (FAO, 2020).

Key relevant UN convention/multilateral treaty

Convention on Biological Diversity (CBD): Established in 1992 and entered into force on 29 December 1993. The convention has three main objectives: the conservation of biological diversity; the sustainable use of the components of biological diversity; and the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources (CBD, no date).

United Nations Convention to Combat Desertification (UNCCD): Established in 1994 to protect and restore land and ensure a safer, just and more sustainable future. The UNCCD is the only legally binding framework set up to address desertification and the effects of drought. The Convention – based on the principles of participation, partnership and decentralisation – is a multilateral commitment to mitigate the impact of land degradation and protect our land so we can provide food, water, shelter and economic opportunity to all people (CCD, no date).

United Nations Framework Convention on Climate Change (UNFCCC): Negotiated from February 1991 to May 1992 and entered into force on 21 March 1994. It seeks to reduce atmospheric concentrations of greenhouse gases, with the aim of preventing dangerous anthropogenic interference with the Earth's climate system. At the Conference of the Parties (COP21) in Paris, on 12 December 2015, Parties to the UNFCCC reached a landmark agreement to combat climate change and to accelerate and intensify the actions and investments needed for a sustainable low-carbon future (UNFCCC, 2015).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Forests face many disturbances that can adversely affect their health and vitality and reduce their ability to provide a full range of goods and ecosystem services.

Forests face many disturbances that can adversely affect their health and vitality and reduce their ability to provide a full range of goods and ecosystem services.

About 98 million ha of forest were affected by fire in 2015 (the latest available global dataset). This was mainly in the tropical domain, where fire burned about 4% of the total forest area in that year. More than two-thirds of the total forest area affected was in Africa and South America (FAO, 2020). In Canada, since 1900, wildfires have consumed an average of 2.5 million ha per year (NRC, no date). In Europe, in 2018, 58,016 fires consumed 350,180 ha, compared to an average of 64,261 fires consuming 406,281 ha per year between 2008 and 2017 (JRC, 2018).

The Global Forest Resources Assessment 2020 noted the extent of different types of disturbance in the forests of the world in 2015 (FAO, 2020).

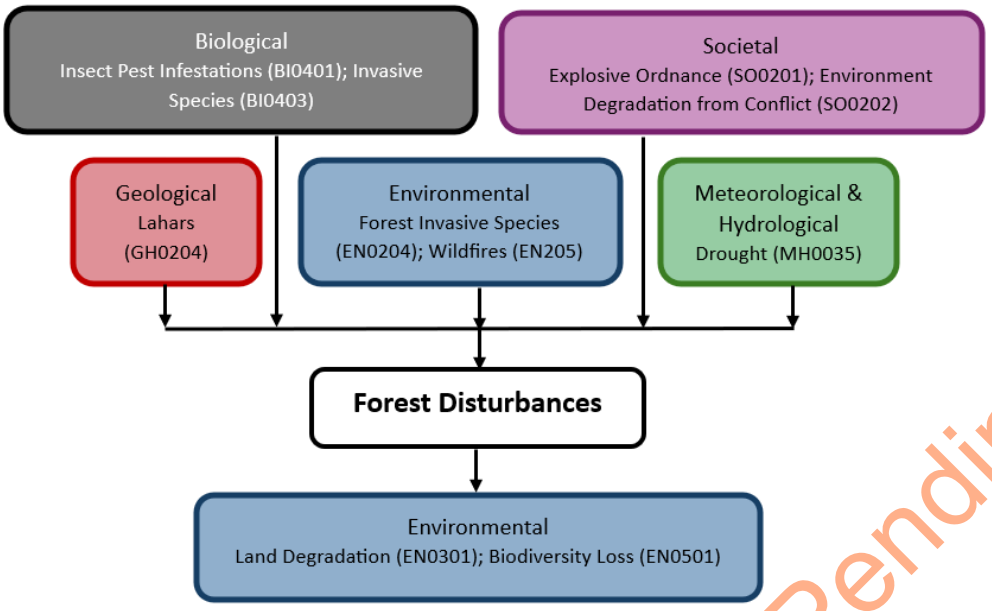
- 51 countries, representing 42% of the world's forest area, reported that 6.6 million ha (0.4% of the forest area of the reporting countries) were affected by disease.
- 62 countries, representing 52% of the world's forest area, reported that 30.2 million ha (1.4% of the forest area of the reporting countries) were affected by insects.
- 48 countries, representing 37% of the world's forest area, reported that 3.8 million ha (0.3% of the forest area of the reporting countries) were affected by severe weather events (FAO, 2020).

Air, water and soil pollution can also contribute to forest degradation. For example, acid rain, resulting from the interaction of sulphur dioxide and nitrogen oxides (mostly produced by the burning of fossil fuels, but also from volcanic eruptions) with water in the atmosphere, damages trees and forests (Zhang, 2023). Acid rain leaches aluminium from the soil, and that aluminium can be toxic to plants, including trees. In addition, other nutrients are also removed from the soil by acid rain, limiting tree growth. At high elevations, acidic fog and clouds might strip nutrients from foliage, leaving trees with brown or dead leaves and needles. The trees are then less able to absorb sunlight, making them weak and less able to withstand freezing temperatures (US EPA, no date).

Impacts: Over 80% of the world's terrestrial biodiversity can be found in forests. Forest disturbance can threaten the survival of many species and reduce the ability of forests to provide essential services such as clean air and water, healthy soils for agriculture, and climate regulation. Additionally, forests support the livelihoods of 1.6 billion people globally, one billion of whom are among the world's poorest (IUCN, 2017).

Multi-hazard Context: The figure below summarises common interactions between forest disturbances and other hazards. This information should be used with caution and not be solely relied upon in disaster risk management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

Preliminary – Corrections Pending



Monitoring: The section and the table below offer an overview of monitoring for forest disturbances. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) disaster risk data/information?	National forest agencies
How is the hazard observed/monitored/forecast?	Ground surveys and remote sensing. Global Forest Watch is an online platform that provides data and tools for monitoring forests. https://www.globalforestwatch.org/about/?lang=en

Risk Management: Many countries have developed policies and laws designed to promote the sustainable and multipurpose use of forests and trees. Such policies and laws serve as a foundation for sustainable forest management by, for example, promoting legal timber trade, involving stakeholders in forest management, addressing forest tenure, and providing incentives (FAO, 2020).

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Preliminary – Corrections Pending

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Coordinating agency or organisation

Food and Agricultural Organization of the United Nations (FAO).

Preliminary – Corrections Pending

EN0204 / ENVIRONMENTAL / Environmental Degradation (Forestry)

Forest Invasive Species

Definition

Forest invasive species are any species that are non-native to a particular forest ecosystem and whose introduction and spread cause, or are likely to cause, socio-cultural, economic or environmental harm, or harm to human health (adapted from FAO, 2015).

Reference

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Preliminary – Corrections Pending

Annotations

Synonyms

Forest pests, Alien forest species, Non-native pests, Invasive forest organisms, Alien invasive species (AIS), Invasive alien plants (IAP)

Additional scientific description

Forest invasive species occur in all major taxonomic groups, from micro-organisms to mammals. These include bacteria, fungi, flatworms, nematodes, insects and arachnids, molluscs, amphibians, reptiles, birds, mammals, grasses, plants, trees and shrubs (FAO, 2009a).

The Food and Agriculture Organization of the United Nations (FAO) reported that (FAO, 2009b):

- Insect pests: The most commonly reported species belong to the orders Coleoptera and Lepidoptera, which together make up over 70% of all insect pest species reported. Hemipteran species were the third most important insect order at 16%. In Africa, Asia and the Pacific, both Coleoptera and Lepidoptera made up the majority of reported pest species. Europe reported more Lepidoptera, while Latin America and the Caribbean reported more Coleoptera.
- Diseases: The majority of species were members of the phylum Ascomycota, which represented almost 60% of all pathogens reported. Basidiomycota species were the next major group at 33%. Four of the regions reported more Ascomycota species, while the Near East reported more Basidiomycota species.
- Other pests: Acarina species were the most common, followed by Artiodactyla species (even-toed ungulates) and Santalales (mistletoes and parasitic plants). Nematodes, rodents and primates were also classified as important pests. Africa reported more primate species, Europe more Artiodactyla, Latin America and the Caribbean more mistletoes and parasitic plants, and the Near East more Acarina species. In the Asia and Pacific region, nematodes and rodents were equally reported.

Plants: Many invasive plants are woody species, including shrubs and trees, and they are among the most widespread and damaging (Richardson & Rejmánek, 2011 as cited in IPBES, 2023). While the exact number of established invasive woody species is unknown, Richardson and Rejmánek (2011; 2013 as cited in IPBES, 2023) compiled a global database listing 751 species–434 trees and 317 shrubs–spanning 90 plant families and 286 genera. These species have spread beyond their native ranges through various pathways, including horticulture (62%: 196 trees and 187 shrubs), forestry (13%), food production (10%) and agroforestry (7%). The regions with the highest numbers of invasive woody species are North America (212 species), the Pacific Islands (208), Australia (203), Southern Africa (178), Europe (134), and the Indian Ocean Islands (126) (IPBES, 2023).

Vertebrates: Invasive vertebrate herbivores have spread to forests in many regions, significantly affecting both aboveground and belowground ecosystems by altering forest community composition. Damage by invasive vertebrates can lead to significant

changes in vegetation structure and disrupt nutrient cycling. In addition to direct consumption, these species can introduce novel disturbances not present in native ecosystems, such as trampling vegetation and modifying habitats. These disturbances can result in ecological impacts that often exceed those caused by herbivory alone, leading to profound changes in forest structure, biodiversity and overall ecosystem health (Wardle & Peltzer, 2017).

Metrics and numeric limits

No globally delivered solution is available for this complex issue, but work continues by several organisations.

- In 2023, IPBES published a report on invasive alien species and their control. This report describes key forest invasive species (IPBES, 2023).
- FAO is collecting data presented in the global review of the status of invasiveness of forest tree species outside their native habitat, available in a database format (FAO, 2009c)
- The Global Invasive Species Programme (GISP), established in 1997, supports the implementation of Article 8(h) of the Convention on Biological Diversity. GISP has prepared a global strategy on invasive alien species, which outlines ten strategic responses (Global Invasive Species Database, no date).

Key relevant UN convention/multilateral treaty

- Convention on Biological Diversity (Article 8(h))
- Kunming-Montreal Global Biodiversity Framework (2022)
- Global Action Plan on Biodiversity and Health, particularly Target 6 and associated actions (Decision adopted by the Conference of the Parties to the Convention on Biological Diversity on 1 November 2024)
- Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)
- International Plant Protection Convention (IPPC)

Examples of hazard drivers, impacts, and risk management

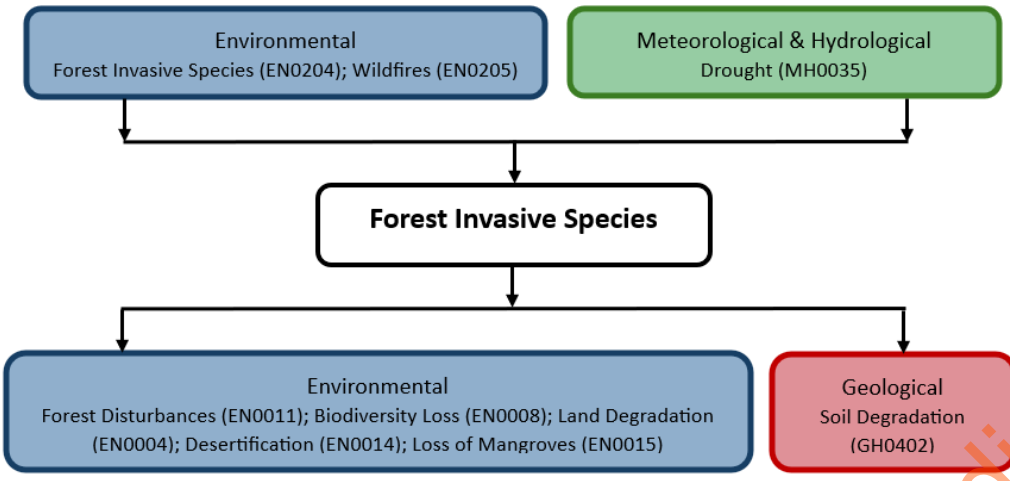
Hazard Drivers: Globally, many forests are continually subject to severe outbreaks of invasive species, which can have major environmental and socio-cultural impacts. The threat of forest invasive species is rising due to increasing global trade and travel and is exacerbated by the impacts of climate change.

Impacts: Forest invasive species significantly impact forest ecosystems, threatening their health, productivity and biodiversity. Effective management and protection are crucial to maintaining these essential services and ensuring forests continue to support both the environment and communities worldwide.

Multi-hazard Context: The figure below summarises common interactions between forest invasive species and other hazards. This information should be used with caution and not be solely relied upon in disaster risk management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

Monitoring: The section and the table below offer an overview of monitoring for forest invasive species. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Preliminary – Corrections Pending



Risk Management: It is essential to protect the world's forests from harm. The global forest area is just over 4 billion ha, representing 31% of the total land area (FAO, 2024a). Managing invasive species and avoiding the introduction of species with known invasive potential require coordinated efforts nationally, regionally and globally (FAO & UNEP, 2020).

Forests provide environmental, economic and social benefits. They yield timber, fuelwood, fibre and other wood and non-wood products, and contribute to rural livelihoods. They offer ecosystem services such as combating desertification, protecting watersheds, regulating climate, maintaining biodiversity, and preserving social and cultural values (FAO, 2024b).

FAO is addressing forest invasive species by:

- Establishing Regional Forest Invasive Species Networks in five regions (Africa, Asia-Pacific, Europe and Central Asia, Latin America and the Caribbean, Near East and North Africa) to facilitate information exchange, awareness, and stakeholder collaboration.
- Developing multiple editions of the Guide to Implementation of Phytosanitary Standards in Forestry, which explains how good forest management and phytosanitary standards can reduce pest spread and support safe trade (FAO, 2011; 2024b).
- Assisting countries in responding to pest outbreaks and establishing long-term forest protection strategies (FAO, 2024c).
- Providing a neutral forum for technical and policy dialogue on invasive species in the forest sector.
- Conducting a review of forest insect pests and diseases in 25 countries across Africa, Asia and the Pacific, Europe, Latin America and the Caribbean, and the Near East (FAO, 2020).
- Publishing reports on global forest health, including insect pests, diseases and invasive species (FAO, 2009b).
- Undertaking fact-finding studies on the invasiveness of forest tree species (FAO, 2018).
- Documenting benefits and drawbacks of Prosopis spp., introduced in dry and semi-arid zones for their survival capacity and land restoration potential (FAO, 2009c).
- Participating in the Inter-agency Liaison Group on Invasive Alien Species (IALG-IAS) under the Convention on Biological Diversity, to coordinate efforts to prevent and mitigate impacts of invasive species (FAO, 2015).

FAO is a member of the Inter-agency Liaison Group on Invasive Alien Species (IALG-IAS) of the Convention on Biological Diversity (CBD) which facilitates cooperation among relevant organisations to support measures to prevent the introduction and mitigate the impacts of invasive alien species (FAO, 2015).

Preliminary - Corrections Pending

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Coordinating agency or organisation

Food and Agricultural Organization of the United Nations.

Preliminary – Corrections Pending

EN0205 / ENVIRONMENTAL / Environmental Degradation (Forestry)

Wildfires

Definition

Any unplanned and uncontrolled vegetation fire that, regardless of ignition source, may negatively affect social, economic or environmental values, and require suppression response or other action according to agency policy (FAO, 2024).

Reference

FAO. 2024. Integrated Fire Management Voluntary Guidelines: Principles and strategic actions. Second Edition 2024. Fire Management Working Paper 41. Rome. https://doi.org/10.4060/cd1090en) (Accessed 21 January 2025).

Preliminary – Corrections Pending

Annotations

Synonyms

Landscape fire, Vegetation fire, Wildland fire, Forest fire, Bushfire, Brush fire, Scrub fire, Peat fire, Veld fire and Grass fire.

Note: These refer to the area or vegetation where the fire is spreading and may also include controlled/prescribed fires. They are not synonyms for “wildfire”. Fires described in these ways may be wildfires, may negatively affect values and may require suppression.

Additional scientific description

Unplanned and uncontrolled vegetation fires (wildfires) may be started by natural causes (lightning, occasionally by burning coal seams or volcanic activity), or–predominantly at the global level–by human activities, primarily through the burning of live or dead vegetation in natural or anthropogenically altered ecosystems (Robinne et al., 2018). These ecosystems include forests, grasslands, shrublands (bush, scrub), organic terrain (peatlands, wetlands), cultivated lands (agricultural and pasture lands, plantations, abandoned cultivated lands) and protected areas (wilderness, conservation sites).

Landscape fire attributes and descriptors include:

- Fuel type (e.g., grass, shrub, forest, peat)
- Fire type (e.g., ground, surface, crown)
- Fire behaviour and emissions (e.g., spread rate, intensity, severity, radiative power, smouldering vs. flaming combustion, gas and particle emissions)
- Temporal and spatial features (e.g., creeping fires, spotting, flashovers, short- to long-duration events; single vs. multiple fires) (GFMC, 2013).

Wildfires may also affect residential and industrial areas, peri-urban fringes, critical infrastructure and remnants of human activities (e.g., waste deposits, mine sites, contaminated lands), potentially resulting in the co-burning of hazardous or toxic substances such as toxic gases (CH0300) and heavy metals (CH0100) (GFMC, no date).

In wildfire suppression, technology has clear limitations. Containment is often subject to weather and fuel conditions. A change in weather or fuel availability is frequently necessary to halt the spread of a wildfire. Understanding these limitations is essential to ensure safe and effective response while minimising risk to firefighters and the public (UNEP, 2022).

Metrics and numeric limits

Satellite data are processed to provide information on burned areas and numbers of fires along with national and agency fire recording and reporting.

FAOSTAT offers data on burned areas and associated emissions. The burned area data derive from the Global Fire Emissions Database Version 3 (GFED3), based on MODIS Collection 5.1 (MCD45A1) (FAO, 2020).

The Global Wildfire Information System (GWIS) provides statistics on average burned area and number of fires by region and country (GWIS, 2019).

Key relevant UN convention/multilateral treaty

The only regional legal agreement currently in place is the Agreement on Transboundary Haze Pollution of the Association of Southeast Asian Nations (ASEAN, 2002).

Examples of hazard drivers, impacts and risk management

Hazard drivers: Unlike most geological and hydro-meteorological hazards, wildfires are primarily influenced by human actions and, to a degree, can be predicted, managed and prevented. Damaging wildfires are often symptomatic of past and present policy, planning and governance choices that have enabled ignition and fire spread across landscapes (Robinne et al., 2018).

Climate change influences wildfire behaviour through changes in weather, which affect vegetation growth and drying (rainfall, temperature, evapotranspiration). By the end of the century, the probability of extreme wildfire events is projected to increase by 31-57% (UNEP, 2022).

Vegetation stressed or killed by pests and disease may increase fuel load and ignition susceptibility. Conversely, wildfires can create vegetation stress that increases vulnerability to pest and disease outbreaks.

Fire is a natural ecological process, but changes to land use are contributing to wildfires. A significant number and area burned by human-caused fires are linked to land-use conversion and agricultural activities. Wildfires are a product of these processes and are partly a function of socio-economic decisions. Reducing the risks of wildfires requires policies and incentives that promote integrated fire management approaches. This includes land and fire management that is well designed, with a balanced combination of policies, a clear legal framework, and incentives that encourage appropriate land and fire use while meeting social, economic, health, and ecosystem needs.

Wildfire occurrence, characteristics, and impacts are closely associated with other hazards. Droughts, heatwaves, and high winds can intensify wildfire severity, size, and duration, complicating control efforts.

Impacts: Human health can be severely affected by wildfires. Certain populations are particularly vulnerable. Biomass smoke contains high levels of particulate matter and toxins. Respiratory morbidity predominates, and epidemiological studies have reported significant associations between wildfire smoke exposure and respiratory morbidity and mortality. Cardiovascular, ophthalmic, and psychiatric problems can also result (Fann et al., 2018), with links to both acute and chronic mental health conditions (Kibble et al., 2023). In addition, severe burns resulting from direct contact with the fire require care in specialised units and carry a risk of multi-organ complications. Access to affected areas and communication with populations living within them is crucial in mitigating risk (Finlay et al., 2012).

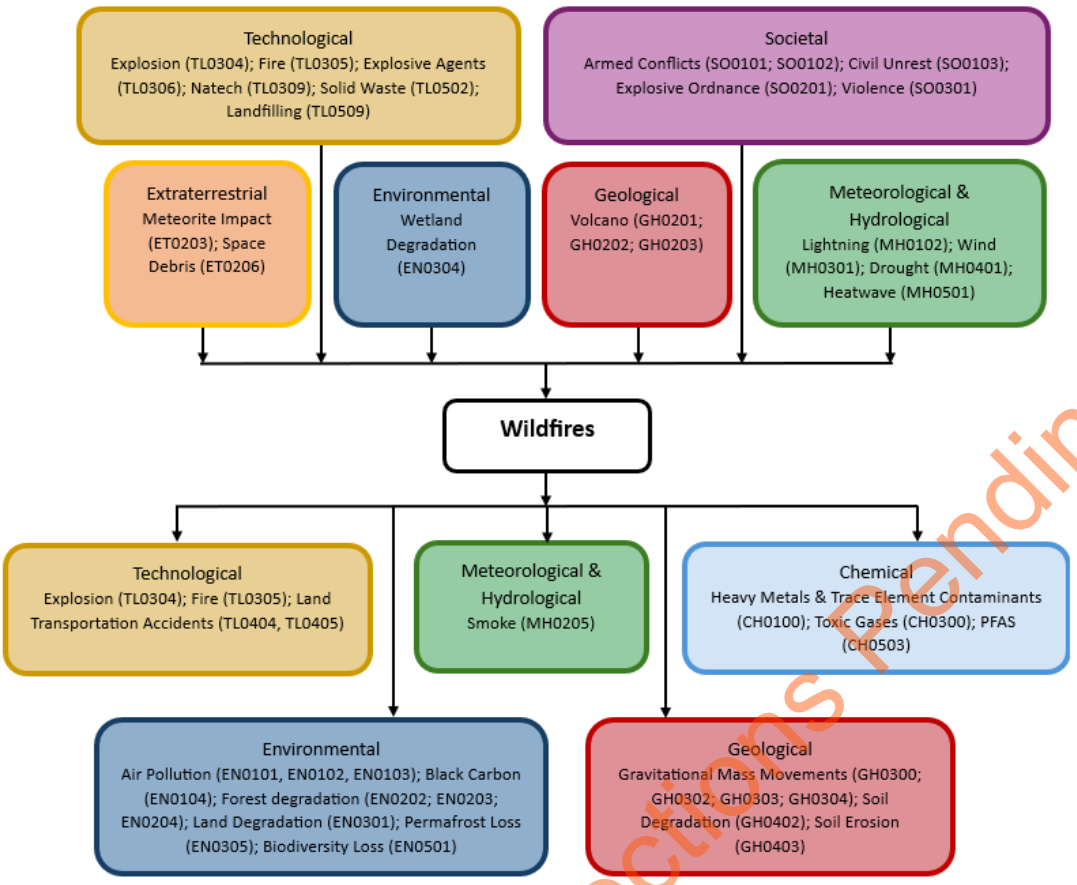
Infrastructure and services, including power, water, communication lines, roads, and railways, are often damaged by wildfires. In addition to firefighting costs, there can be very large financial costs associated with rebuilding homes, businesses, and entire communities that have been damaged or destroyed by a major fire event, as well as broader economic impacts.

The effects of wildfires on vegetation cover and soil stability may create secondary hazards or subsidiary perils, such as post-fire landslides, mudslides, flash floods, erosion, and siltation (triggered by post-fire rainfall on fire-disturbed surfaces) (Kibble et al., 2023).

Fires burning on terrain contaminated by radioactivity may lead to uncontrolled redistribution of radioactive particles. Wildfires burning into residential and industrial areas and waste deposits may generate toxic pollutants. Fires burning on terrain containing unexploded ordnance and landmines could result in injuries and fatalities (Finlay et al., 2012).

Multi-hazard Context: The figure below summarises common interactions between wildfires and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

Preliminary – Corrections Pending



Monitoring: The section and the table below offer an overview of monitoring wildfires. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) disaster risk data/information?	Weather service agencies, fire authorities, NASA FIRMS
How is the hazard observed/monitored/forecast?	Monitoring the weather conditions such as drought and heatwaves Monitoring the soil humidity and the vegetation conditions Surveillance of areas prone to wildfires Active fire detections: different data sources are useful in different ways for identification and response to the hazard, e.g. precision of polar-orbiting detection vs. higher frequency geostationary detection See: https://doi.org/10.1016/j.rse.2021.112694 Global active fire data: https://firms.modaps.eosdis.nasa.gov/map/

Risk Management: Integrated fire management is key to adapting to current and future changes in global wildfire risk. It consists of five interlinked and often overlapping phases: review and analysis, risk reduction, readiness, response, and recovery (the 5Rs), which are applied and promoted by FAO and the World Bank in their approaches and project design. Notably, residual risks will remain, and planning for impacts and recovery is required for wildfires.

Communities must be engaged meaningfully in planning, mitigating, and reducing the hazard on their landscape to reduce wildfire risk. This requires a shift in the social approach to living with fire and being prepared. There is growing recognition of the important role that Indigenous Peoples and local knowledge holders can play in informing land management practices that assist in the prevention and mitigation of wildfires. Importantly, this must include engagement to support and integrate Indigenous, traditional, and contemporary fire management practices into policy.

An important element of integrated fire management is rebalancing investments from readiness and response towards proactive wildfire mitigation and management. Wildfire risk reduction activities represent a sound investment as they reduce the potential impacts of wildfires and, in the long term, are more cost-effective than response, recovery, and restoration following extreme events.

Preliminary – Corrections Pending

Almost all disastrous wildfire events are associated with anomalous meteorological or climatic conditions (Bowman et al., 2017). To mitigate or prevent wildfire disasters, fire managers require early warning of extreme fire danger conditions. This allows time to implement fire prevention, detection, and pre-suppression preparedness action plans before disaster wildfires occur. Fire Danger Rating Systems are the cornerstone of fire management decision-making and are used with forecasted meteorological data to provide early warning of wildfire potential (de Groot et al., 2014).

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Coordinating agency or organisation

Food and Agriculture Organization of the United Nations with input from the Global Fire Monitoring Center.

Preliminary – Corrections Pending

EN0206 / ENVIRONMENTAL / Environmental Degradation

Desertification

Definition

Desertification refers to land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities (UNCCD, 2017).

Reference

UNCCD, 2017. UNCCD Terminology: Desertification. United Nations Convention to Combat Desertification (UNCCD). https://knowledge.unccd.int/taxonomy/term/1338 (Accessed 21 January 2025).

Annotations

Synonyms

Dryland degradation.

Additional scientific description

Desertification and land degradation are very serious challenges. They lead to hunger and poverty, drive unemployment, forced migration and conflict, while increasing the risk of extreme weather related to climate change (FAO, 2020a).

The most widely accepted definition in China for desertification is that given by Zhu et al. (1989, cited by FAO, 1997). Zhu describes desertification as the degradation process in environments similar to that of deserts consisting of blown and undulating sand sheets and mobile dunes which occurs when fragile ecosystems such as those with loose sandy surfaces in arid, semi-arid and sub-humid zones are exposed to drought and frequent wind. This process reduces biomass productivity and arable land. The environmental changes caused by desertification produce desert-like landscapes in aboriginal non-desert areas or steppes (FAO, 1997).

Desertification is a silent, invisible crisis that is destabilising communities on a global scale. As the effects of climate change undermine livelihoods, inter-ethnic clashes are breaking out within and across states, and fragile states are turning to militarisation to control the situation (UNCCD, 2014).

In 2008, food insecurity triggered riots in over 30 countries. Drylands, which make up nearly 34% of the land mass and are a major source of food security especially for the poor, are being degraded daily (UNCCD, 2014).

It is estimated that 135 million people are at risk of being displaced by desertification. The problem is most severe in sub-Saharan Africa, particularly in the Sahel and the Horn of Africa (UNCCD, 2014).

A total of 842 million people, or about one in eight people in the world, were estimated to be suffering from chronic hunger in 2011-2013 and 12 million hectares of productive land become barren every year due to desertification and drought alone, which is a lost opportunity to produce 20 million tonnes of grain (UNCCD, 2014).

Agricultural yields could fall by up to 50% in some African countries if production practices are not changed (UNCCD, 2014).

Metrics and numeric limits

Key facts from Action Against Desertification: land degradation affects almost 2 billion ha of land worldwide, home to 3.2 billion people; every year, 24 billion tonnes of fertile soils are lost due to erosion; and 12 million ha of land are degraded each year - this is 23 ha per minute (FAO, 2020a). 0a).

Key relevant UN conventions or multilateral treaties

Established in 1994, the United Nations Convention to Combat Desertification (UNCCD) is the sole legally binding international agreement linking environment and development to sustainable land management (UNCCD, 2017). The Convention addresses specifically the arid, semi-arid and dry sub-humid areas, known as the drylands, where some of the most vulnerable ecosystems and peoples can be found.

Article 1: 'Combating desertification' includes activities which are part of the integrated development of land in arid, semi-arid and dry sub-humid areas for sustainable development, which are aimed at prevention and/or reduction of land degradation, rehabilitation

Preliminary – Corrections Pending

of partly degraded land, and reclamation of desertified land (UNCCD, 2017).

Examples of hazard drivers, impacts and risk management

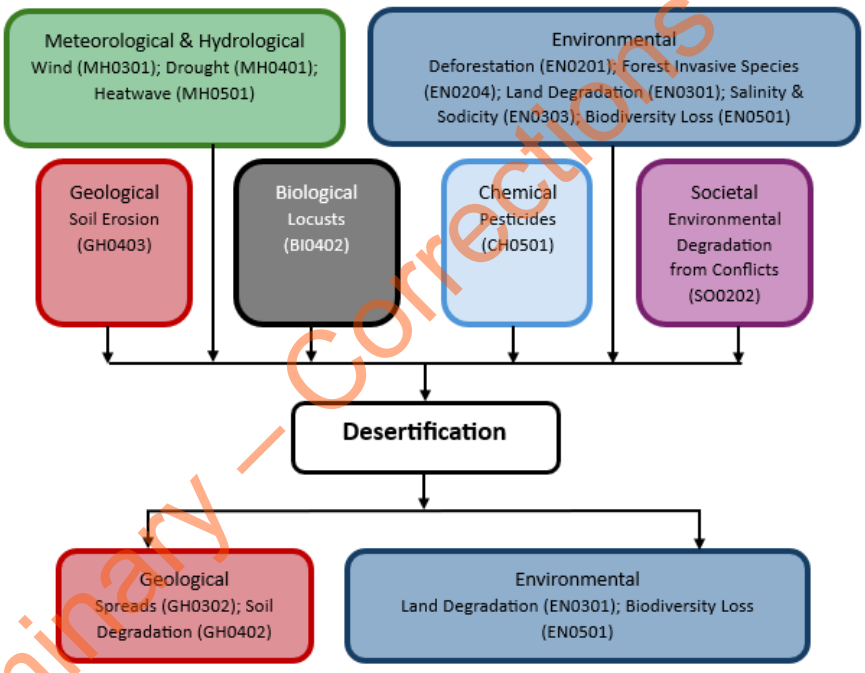
Hazard Drivers: Some of the drivers of desertification include those related to climatic variations, such as drought as well as strong winds and heavy rainfall, which destroy and damage vegetation, and human activities, such as over-cultivation, overgrazing, unsustainable agricultural practices (from not rotating crops to unprotected soils or chemical fertiliser and pesticide use), and deforestation, which also increases the risk of fires, among others (UNCCD, 2011).

In the climate change context, increased global temperatures leading to higher evaporation and reduced soil moisture can also increase the risk of desertification.

Desertification combined with land degradation and drought in rural areas where people rely on limited productive land resources is one of the drivers of forced migration (UNCCD, 2014).

Impacts: The effects of desertification are increasingly felt globally as victims turn into refugees, internally displaced people and forced migrants.

Multi-hazard Context: The figure below summarises common interactions between desertification and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: FAO monitors desertification using Land Degradation Assessment in Drylands (LADA) through remote sensing and socio-economic analysis.

Risk Management: At the UN General Assembly in 2012, desertification, land degradation and drought were addressed in the resolution adopted by the General Assembly on 27 July 2012 (UNGA, 2012). Two quotes of particular relevance are included here:

- "We stress that desertification, land degradation and drought are challenges of a global dimension and continue to pose serious challenges to the sustainable development of all countries, in particular developing countries."
- "We recognise the need for urgent action to reverse land degradation. In view of this, we will strive to achieve a land-degradation-neutral world in the context of sustainable development. This should act to catalyse financial resources from a range of public and private sources."

Over 2 billion ha of land have potential for recovery through restoration approaches that combine activities like forestry with farmland re-vegetation. The restoration of over 5 million ha of land by communities that live across Burkina Faso, Niger and Mali has reversed outward migration flows (UNCCD, 2014).

Action Against Desertification (started in 2014) is an initiative of the African, Caribbean and Pacific Group of States (ACP) to restore drylands and degraded lands in Africa, the Caribbean and the Pacific to tackle the detrimental social, economic and environmental impact of land degradation and desertification (FAO, 2020b).

Action Against Desertification supports local communities, government and civil society in six African countries – Burkina Faso,

Preliminary – Corrections Pending

Ethiopia, The Gambia, Niger, Nigeria and Senegal – as well as Fiji and Haiti to restore degraded land and to manage fragile ecosystems in a sustainable way. It is using a mix of the following activities (FAO, 2020b):

- Land restoration: putting rural communities at the heart of restoration and upscaling interventions to meet the massive needs
- Non-timber forest products: support economic growth and sustainable management of natural resources
- Capacity development: strengthening capacities in sustainable land management and land restoration
- Monitoring and evaluation: collecting data, keeping track of progress, measuring impact
- Information sharing: knowledge exchange and awareness-raising about land degradation and desertification
- South-South cooperation: sharing lessons learned on how to reverse land degradation

In sub-Saharan Africa, where half a billion inhabitants are rural, the majority live off the land and desertification is a constant threat to their livelihoods. More than 3.2 billion people in the world depend on degraded land for their livelihoods, and 74% of them are poor. Under the United Nations Convention to Combat Desertification (UNCCD), the international legal framework for tackling desertification, land degradation and drought, 169 of its 194 Parties have declared that they are affected by desertification. Action

Against Desertification is a key partner of the Great Green Wall initiative, Africa's flagship programme to combat the effects of climate change and desertification across North Africa, the Sahel and the Horn of Africa (FAO, 2020b).

Key results to date from Action Against Desertification (FAO, 2020c) are summarised in the table below:

35,000 ha under restoration 2700,000 seedlings used 82,700 kg of seeds used 100 species used 500,000 people reached	7925 ha under restoration 593,000 seedlings used 3000 people reached	2000 ha under restoration 8000 kg of seeds used 1000,000 seedlings used 6200 people reached

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Coordinating agency or organisation

Food and Agricultural Organization of the United Nations.

Preliminary – Corrections Pending

EN0207 / ENVIRONMENTAL / Environmental Degradation

Loss of Mangroves

Definition

Mangroves are distinctive tropical and sub-tropical, woody plants that grow at the interface/intertidal zone between land and sea, where they exist in conditions of high salinity, extreme tides, strong winds, high temperatures and muddy, anaerobic soils (Kathiresan and Bingham, 2001). The destruction of mangrove habitat is caused by both human and natural causes. Humans have cleared mangrove forests to expand farmlands, aquaculture ponds or urban areas. Natural stressors, such as sediment erosion, extreme storm surges or drought have also resulted in mangrove habitat loss. The loss of mangroves has devastated coastal communities, which depend on them for socio-economic activities and environmental conservation, especially in regions with low mangrove diversity and coverage.

Preliminary – Corrections Pending

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Annotations

Synonyms

Mangrove loss, mangrove deforestation.

Additional scientific description

There are over 70 species of mangroves worldwide (Polidoro et al., 2010). Distinct species make up a forest, which can be categorised as fringe, riverine, overwash, basin, or dwarf (Lugo and Snedaker, 1974). The ecosystem services that healthy mangrove forests provide include coastal protection, timber and fuel supply, fisheries generation, and eco-tourism support (Mukherjee et al., 2014). They are also crucial for climate change mitigation, storing more carbon than other ecosystems due to their high carbon density (Temmink et al., 2022).

Metrics and numeric limits

The Global Mangrove Watch (GMW), an initiative of the Global Mangrove Alliance, is an online platform that provides remote sensing data and tools for monitoring mangroves. The GMW comprises the Japan Aerospace Exploration Agency Kyoto and Carbon Initiative, Aberystwyth University, Solo Earth Observation, The Nature Conservancy, and Wetlands International. The GMW also hosts the

official mangrove datasets used by the United Nations Environment Programme (UNEP) for reporting on Sustainable Development Goal 6.6.1 (change in the extent of water-related ecosystems over time) (GMW, last accessed 13 May 2024).

The most recent global extent maps are for 2020, and historical assessments span as far back as 1996. Between 1996 and 2020, there was a total net global mangrove loss of 3.4% of area coverage, which equates to a loss of 5,245 km² (Bunting et al., 2022).

The availability of GMW has resulted in the Mangrove Restoration Potential Map (MRP Map), a unique interactive tool developed to explore potential mangrove restoration areas worldwide and model the potential socio-ecological benefits associated with such restoration. The mapping tool was developed by The Nature Conservancy and the International Union for Conservation of Nature (IUCN), in collaboration with the University of Cambridge (Worthington and Spalding, 2018).

The MRP Map includes assessments of global maximum mangrove extent, mangrove deforestation, and potential restorable area. From 1996 to the present, 1,389 km² of mangroves have been degraded, and a total of 8,120 km² has the potential to be restored.

Data suggest an average loss rate of 0.13% annually from 1996 to 2016, higher than the average for tropical and sub-tropical forest losses (Goldberg et al., 2020). At national levels, losses are recorded in 97% of the countries and territories with mangroves (105 out of 108 countries), while degradation is recorded in 76% (82 out of 108 countries) (Worthington and Spalding, 2018).

Key relevant UN conventions and /multilateral treaties

The Convention on Wetlands, adopted in 1971, was one of the earliest policy frameworks for the conservation and management of coastal wetlands, including mangroves (UNESCO, 1971). In 2015, the Sendai Framework for Disaster Risk Reduction (2015-2030) acknowledged, although not explicitly, the protective role of mangroves in the potential reduction of coastal disaster risks (UNDRR, 2015). Furthermore, the 2016 United Nations General Assembly resolution on oceans and the law of the sea (UN/A/RES/71/257) recognised the socio-ecological value of mangroves through the generation of vital ecosystem services, including coastal protection, carbon storage, sustainable livelihoods, food security, and biodiversity conservation. In 2019, the United Nations Environment Assembly adopted a resolution focused on the sustainable management of the global health of mangroves (UNEP, 2019). The Paris Agreement of 2015 led 97 countries in 2023 to incorporate climate adaptation and/or mitigation strategies in coastal and marine ecosystems, including mangroves, into their Nationally Determined Contributions (Lecerf et al., 2023). UNESCO's proclamation of the International Day for the Conservation of the Mangrove Ecosystem also underscores the global commitment to conserve and restore these vital ecosystems. The conservation and restoration of mangroves aid in achieving multiple Sustainable Development Goals (SDGs), most directly SDG 14 – to conserve and sustainably use the oceans, seas, and marine resources for sustainable development. It further contributes to SDG 2 – zero hunger, SDG 6 – clean water and sanitation, SDG 8 – economic growth, and SDG 13 – climate action (United Nations, 2015).

Examples of hazard drivers, impact and risk management

Hazard Drivers: Mangroves are vulnerable to sea-level rise when they are unable to accrete sediments in pace with the sea-level rise, which results in their submergence and subsequent loss. This is compounded by their inability to migrate inland to higher elevations when suitable migration space is lacking due to coastal development or natural barriers, resulting in coastal squeeze (Alongi, 2015). Furthermore, mangroves are sensitive to other climatic events, such as storms, high water events, precipitation and drought, and climate fluctuations, such as the El Niño-Southern Oscillation (ENSO) (Field, 1995). Mangroves are most vulnerable when they experience combinations of these climatic events; for example, mangroves along a 1,000 km length in northern Australia recently experienced substantial dieback after an ENSO event led to a temporary sea-level drop and a marked reduction in precipitation (Duke et al., 2017).

The extent of mangrove loss varies regionally, with Southeast Asia representing a particular hotspot, accounting for 47% of the global net mangrove loss between 1996 and 2020, with the primary drivers of this loss also being regionally dependent (Bunting et al., 2022; UNEP-WCMC, 2014). Mangrove loss is primarily due to the deforestation of existing mangrove areas, with around 62% (Goldberg et al., 2020) attributed to aquaculture and agriculture (including oil palm, rice cultivation, and other forms of agriculture and undefined uses). Other significant causes include direct and indirect settlement (urbanisation), which involves the clearing of mangroves for housing and other infrastructure, and development activities that alter hydrology and sediment inputs, or create severe pollution, leading to mangrove loss (FAO, 2023). An estimated 26% of mangrove loss is also due to natural causes, which occur as a result of changes in riverbeds, sediment inputs, or sea level (FAO, 2023).

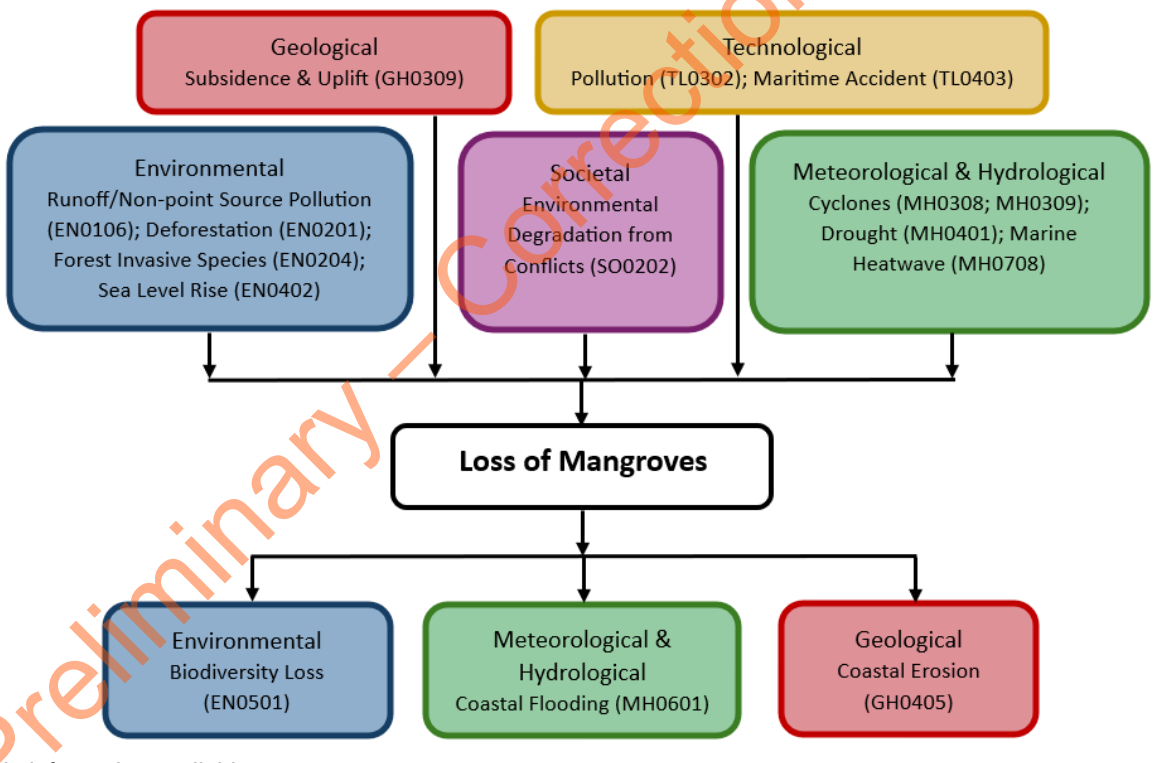
Impacts: The loss of mangroves and the ecosystem services they generate can negatively affect local coastal communities and global populations. These include reduced ability to mitigate climate change as a sink of atmospheric carbon; reduced disaster risk reduction and lower protection of coastal communities from hazards, such as sea-level rise and storm surges; reduced adaptive capacity of coastal populations through reduced access to sources of food, fibres, timber, chemicals, and medicines. The loss of these resources often translates into a loss of revenue, as local fisheries, tourism, and related industries are sustained by the mangrove forests. In addition, as mangroves store a large amount of carbon in their soils, mangrove deforestation can release 25-100% of the total cleared biomass as carbon dioxide (CO_2) emissions and as much as 45% of soil carbon is lost within three years (Lovelock et al., 2017). Emissions from wetlands are explicitly considered in national greenhouse gas emissions reporting through the Intergovernmental Panel on Climate Change. Mangrove loss may also have unintended impacts on other connected coastal ecosystems, such as seagrass meadows or coral reefs (UNEP-WCMC, 2006).

Preliminary – Corrections Pending

Mangroves play a crucial role in mitigating the impacts of natural hazards, such as storms, floods, erosion, strong winds, and tsunamis. In that way, they contribute to disaster risk reduction. Studies indicate that ecologically healthy mangroves played a crucial role in saving lives and property during the tsunami (Danielsen et al., 2005; Goda et al., 2019). For example, during the 2018 earthquake in Palu Bay, Indonesia, tsunamis caused severe damage, with some areas experiencing waves as high as 2 metres. Homes located directly in front of mangrove forests were completely destroyed or swept away, while those sheltered behind the mangrove forests were largely spared (Goda et al., 2019). Similarly, the 2004 Indian Ocean tsunami showed that areas protected by mangroves suffered less damage than areas without such natural barriers (Danielsen et al., 2005). In Indonesia, land subsidence worsens the effects of sea-level rise on coastal ecosystems and communities, impacting both mangroves and coastal villages. However, mangroves experience subsidence to a lesser extent than villages, highlighting their protective role in reducing coastal flooding (Nurhidayah et al., 2022). A model also revealed that developing countries and small islands gain the most economic benefit from flood protection provided by mangroves. In Belize, Suriname, and Mozambique, these benefits represent over 15% of their national GDP (Menéndez et al., 2020).

However, the loss of mangroves reduces their ability to provide protective services. As mangrove forests degrade or are lost, the natural buffer they provide against extreme events is lost (Goldberg et al., 2020). This, in turn, increases both the frequency and severity of damage caused by natural hazards and leaves coastal communities more vulnerable to disasters. Mangrove loss will eliminate their function as effective natural filters for chemical pollutants (Sultana et al., 2023), leading to a decline in water and sediment quality.

Multi-hazard Context: The figure below summarises common interactions between the loss of mangroves and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Preliminary – Corrections Pending

Monitoring: No information available

Risk Management: Mangrove loss can be reduced or managed by efforts to stabilise existing mangrove extent and restore (replant) mangroves that have been lost. Mangrove coverage can be stabilised by conservation efforts, including increased protected area management and enforcement of national laws that prohibit mangrove loss. Furthermore, it is important to integrate local knowledge and increase community participation. In addition, the promotion of flexible and robust governance is essential for dealing with uncertainty, complexity, and dynamics of mangroves and ecosystems (e.g. adaptive management). Investigating, monitoring, and mitigating drivers of mangrove loss on regional and national levels are critical to maintaining existing mangrove forests.

Mangrove coverage can be increased by rehabilitation of previously deforested mangrove areas, such as the rehabilitation of abandoned aquaculture ponds. Potentially 800,000 hectares globally may be biophysically suitable for rehabilitation (Worthington and Spalding, 2018), although several socio-economic and governance challenges exist. These may reduce the area that is ultimately feasible to rehabilitate. The success of these interventions requires an expansion of research on the basic ecology and hydrology of mangroves and social sciences of human-mangrove interactions. Understanding local enabling conditions (social equity, environmental sustainability, and economic viability) is key to successful mangrove management and its associated blue economy.

Mangroves play a crucial role in the resilience of coastal ecosystems, as they can adapt to rising sea levels through enhanced sedimentation. However, this ability can be suddenly lost, especially when mangroves experience long-term degradation. In such cases, ecosystems can rapidly revert to earlier conditions, leading to sediment loss and reduced functionality. To prevent this, early warning systems and monitoring are essential. These strategies help anticipate mangrove loss, enhancing ecological functions and services such as coastal protection and disaster mitigation. For example, in China, regular monitoring supports the development of tailored management measures, allowing for prompt responses to changes in ecosystem stability (Zheng, 2023). There are more datasets as well that could help comprehensive mangrove monitoring (Worthington et al., 2020).

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Preliminary – Corrections Pending

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Coordinating agency or organisation

Not Identified.

Preliminary – Corrections Pending

EN0301 / ENVIRONMENTAL / Environmental Degradation

Land Degradation

Definition

Land degradation is the reduction or loss, in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns such as soil erosion caused by wind and/or water; deterioration of the physical, chemical and biological or economic properties of soil; and long-term loss of natural vegetation (UNCCD, 1993).

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Annotations

Synonyms

None identified.

Additional scientific description

Land degradation is the reduction in the capability of the land to produce benefits from a particular land use under a specified form of land management (FAO, 1999).

More than 60% of human-induced land degradation is happening in agricultural lands (cropland and pastureland). Food production is reduced and the entire agrifood system is under pressure. The restoration of agricultural land is a priority to ensure the achievement of several SDGs, such as food security and land degradation neutrality.

In the soil conservation arena, the terms soil degradation and land degradation are sometimes incorrectly used interchangeably, with soil erosion regarded as synonymous with both. However, there is more to soil degradation than just soil erosion, and land represents a broader concept than simply soil. As with its use in the context of land evaluation (FAO, 1976), the term land refers to all natural resources which contribute to agricultural production, including livestock production and forestry. Land thus covers climate, landforms, water resources, soils and vegetation (including both grassland and forests) (FAO, 1999).

There are a number of interrelated land degradation components, all of which may contribute to a decline in agricultural production. The most important according to Douglas (1994) cited by FAO (1999):

- *Soil degradation:* decline in the productive capacity of the soil as a result of soil erosion and changes in the hydrological, biological, chemical and physical properties of the soil.
- *Vegetation degradation:* decline in the quantity and/or quality of the natural biomass and decrease in the vegetative ground cover.
- *Water degradation:* decline in the quantity and/or quality of both surface and groundwater resources.
- *Climate deterioration:* changes in the micro- and macro-climatic conditions that increase the risk of crop failure.
- *Losses to urban/industrial development:* decline in the total area of land used, or with potential, for agricultural production as a result of arable land being converted to urban, industrial and infrastructure uses (FAO, 1999).

Preliminary – Corrections Pending

Examples of causes of different types of land degradation include water erosion, wind erosion, soil fertility decline, waterlogging, salinisation, lowering of the water table, deforestation, forest degradation and rangeland degradation (FAO, 1994).

Soil loss from conventionally tilled land exceeds the rate of soil formation by more than two orders of magnitude (medium confidence). An estimated 3.2 billion people, or a quarter of the world's population, depend directly on land that is being degraded (FAO, 2021).

Metrics and numeric limits

Nachtergaele et al. (2011) reported that there is a plethora of methods, indicators and recent studies concerning specific aspects of land degradation at local and national levels. An inventory carried out by the United Nations Convention to Combat Desertification (UNCCD) revealed more than 900 different land degradation indicators used in a sample of UNCCD countries. Efforts for harmonisation are ongoing. Eleven indicators have been provisionally defined by the UNCCD, and 22 metrics have been selected to be tested for their measurement. Practical monitoring may use any of the following:

- The Land Degradation Assessment in Drylands (LADA) / World Overview of Conservation Approaches and Technologies (WOCAT) participatory assessment methodology can be used at the subnational level. The main parameters describe the state, cause and impact of degradation. At the same time, the type and extent of sustainable land management interventions are inventoried.
- The coupled human-environment promotes the integrated consideration of biophysical and socio-economic parameters linking institutional and policy considerations with land degradation. These consider threshold tipping points beyond which systems can no longer be restored.
- Remote sensing approaches have the significant advantage that data are continuously collected objectively and as such are ideally suited for monitoring purposes. Reliability issues and capacity needs remain as weakness points.
- Local sampling techniques and surveys are objective and the most detailed of all but are more costly and time-consuming (Nachtergaele et al., 2011).

Key relevant UN conventions or multilateral treaties

United Nations Convention to Combat Desertification (UNCCD) (UNCCD, 1994). The UNCCD 2018-2030 Strategic Framework (UNCCD, 2017).

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Land-use changes and unsustainable land management are direct human causes of land degradation (very high confidence), with agriculture being a dominant sector driving degradation (very high confidence) (Nachtergaele et al., 2011).

The expected increase in the frequency and severity of hazards, such as forest fires, floods, landslides and droughts, may aggravate land degradation (Nachtergaele et al., 2011).

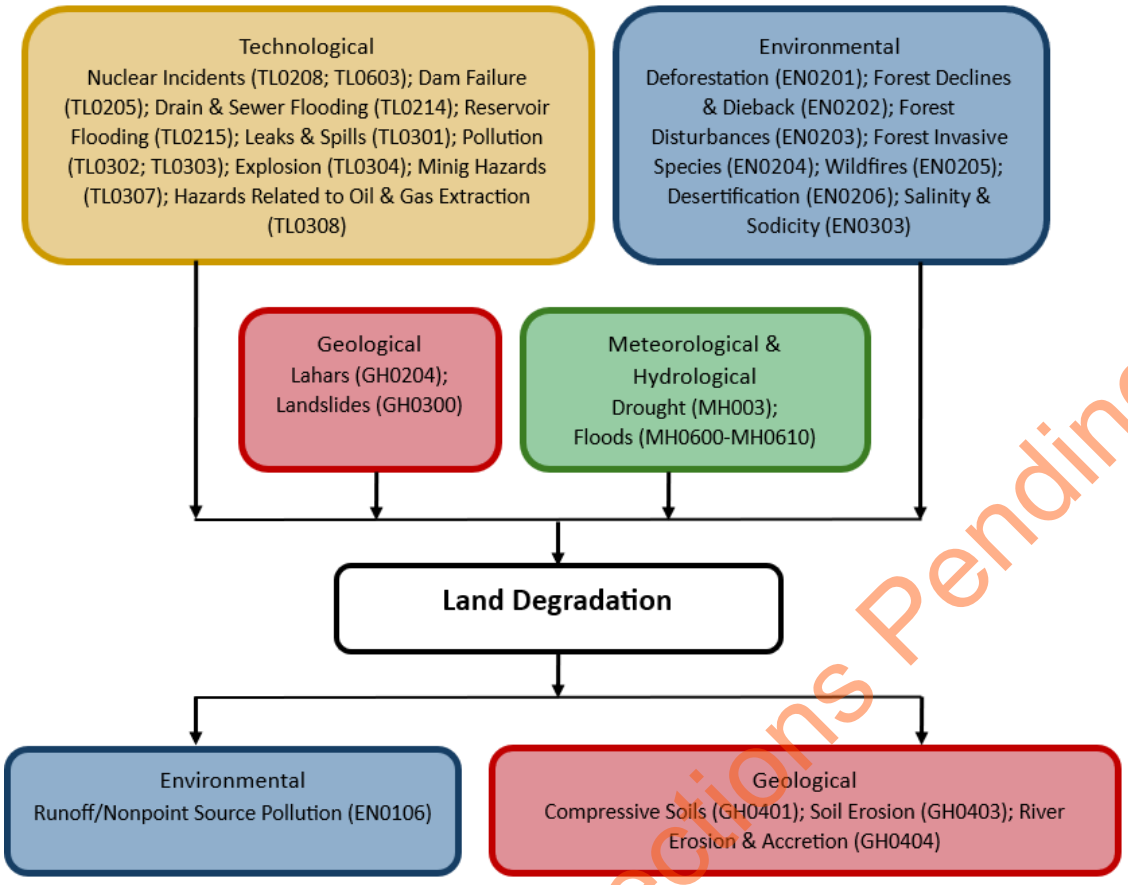
Impacts: Land degradation has both on-site and off-site effects. On-site effects are the lowering of the productive capacity of the land, causing either reduced outputs (crop yields, livestock yields) or the need for increased inputs. Off-site effects of water erosion occur through changes in the water regime, including decline in river water quality, and sedimentation of river beds and reservoirs. The main off-site effect of wind erosion is overblowing, or sand deposition (FAO, 1994).

In their 2019 review on land degradation for the Intergovernmental Panel on Climate Change (IPCC), Olsson et al. (2019) reported that land degradation adversely affects people's livelihoods (very high confidence) and occurs over a quarter of the Earth's ice-free land area (medium confidence). The majority of the 1.3 to 3.2 billion affected people (low confidence) are living in poverty in developing countries (medium confidence).

Land degradation affects humans in multiple ways, interacting with social, political, cultural and economic aspects, including markets, technology, inequality and demographic change (very high confidence). Land degradation impacts extend beyond the land surface itself, affecting marine and freshwater systems, as well as people and ecosystems far from the local sites of degradation (very high confidence) (Olsson et al., 2019).

Multi-hazard Context: The figure below summarises common interactions between land degradation and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

Preliminary – Corrections Pending



Monitoring: No information available

Risk Management: The Food and Agriculture Organization of the United Nations (FAO) assists member countries in assessing the physical, socio-economic, institutional and legal potential and constraints on land use, with the aim of achieving the optimal and sustainable use of land resources and empowering people to make informed decisions on the allocation of those resources.

In this regard, FAO's work to reduce land degradation focuses on e.g. promoting sustainable land management practices, enhancing resource-use efficiency, optimising the use of inputs, sustaining the full range of ecosystem functions (e.g. the provisioning of food, fibre and energy; soil health; water quality; cultural values; and biodiversity conservation) and integrated land use planning (FAO, 2020).

Preliminary – Corrections Pending

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Coordinating agency or organisation

Food and Agricultural Organization of the United Nations.

Preliminary – Corrections Pending

EN0302 / ENVIRONMENTAL / Environmental Degradation

Sea Water Intrusion

Definition

Seawater intrusion is the process by which saltwater infiltrates a coastal aquifer, leading to contamination of fresh groundwater (Prince Edward Island Department of Environment, Labour and Justice, 2011).

Reference

Prince Edward Island Department of Environment, Labour and Justice, 2011. Saltwater Intrusion and Climate Change: A primer for local and provincial decision- makers. https://www.princeedwardisland.ca/sites/default/files/publications/saltwater_intrusion_and_climate_change.pdf (Accessed 13 October 2020).

Preliminary – Corrections Pending

Annotations

Synonyms

Saltwater intrusion, Saltwater encroachment.

Additional scientific description

Saltwater intrusion (SWI) refers to the process by which seawater infiltrates coastal groundwater systems, thus mixing with the local freshwater supply. Groundwater is stored in the pores and fractures of rock beneath the surface, and the rock formations containing groundwater are referred to as aquifers (Prince Edward Island Department of Environment, Labour and Justice, 2011).

The occurrence of SWI has been shown to take a variety of distinct forms. Two major categories are proposed to classify seawater intrusion: 'passive SWI', referring to inland movements of seawater in areas where fresh groundwater flows towards the coastline, and 'active SWI', whereby seawater moves in the same direction as fresh groundwater flow (Werner, 2017).

Seawater intrusion (SWI) is a natural process encountered in almost all coastal aquifers around the globe, however with different intrusion degrees based on multiple geological, hydrological, and environmental factors. The problem is exacerbated through anthropogenic activities, particularly the excessive extraction of groundwater (Geosciences Australia, 2014; Kassem et al., 2024).

Aquifers are naturally replenished (or recharged) by way of precipitation (rain, snowmelt) that seeps into the ground and eventually reaches the water table. Because saltwater is denser than freshwater, this saline groundwater may 'intrude' beneath freshwater, creating a saltwater 'wedge' at the coastline. In addition to the local hydraulic and density gradients, the nature of this saltwater-freshwater interaction is controlled by many factors, including the characteristics of the aquifer (such as permeability and thickness) and the characteristics of any layers of rock underlying or overlying the aquifer (confining layers) (Prince Edward Island Department of Environment, Labour and Justice, 2011; Government of Australia, 2015; Chun et al., 2018).

Metrics and numeric limits

Surface water salinity is described by units of electrical conductivity (EC). Groundwater salinity is described by units of parts per million (ppm). Scientific reports use decisiemens per metre (dS/m) as the main unit of measure (USGS, 2019).

Salinity is the measure of the concentration of dissolved (soluble) salts in water from all sources. The concentration is the amount (by weight) of salt in seawater, as expressed in parts per million (ppm) (USGS, 2019).

Key relevant UN convention / multilateral treaty

Not identified.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Many factors contribute to the severity of the seawater inclusion, among others, pumping and recharge events, aquifer geometry (specifically, depth at the seaside), geological and hydrological parameters, boundary conditions, natural freshwater flux from the land side, and land use (Werner et al., 2013).

With rising sea levels, saline water intrusion into coastal aquifers, surface waters and soils are expected to become more frequent and advance further inland. Salinisation of groundwater, surface water and soil resources also increases with land-based drought events and decreasing river discharge in combination with water extraction and sea-level rise (Oppenheimer et al., 2019).

A major factor of seawater inclusion is groundwater abstraction. Further natural and anthropogenic drivers of seawater intrusion are discussed by White and Kaplan (2017).

Impacts: Seawater intrusion can render freshwater drinking water supplies unusable, especially dangerous for people with hypertension who need to reduce their salt intake (Government of British Columbia, no date).

In low-lying atoll islands, sea-level rise will make seawater intrusion in shallow aquifers more frequent, in fact too frequent for the aquifers to recover between intrusions, resulting in atolls becoming uninhabitable (Storlazzi et al., 2018).

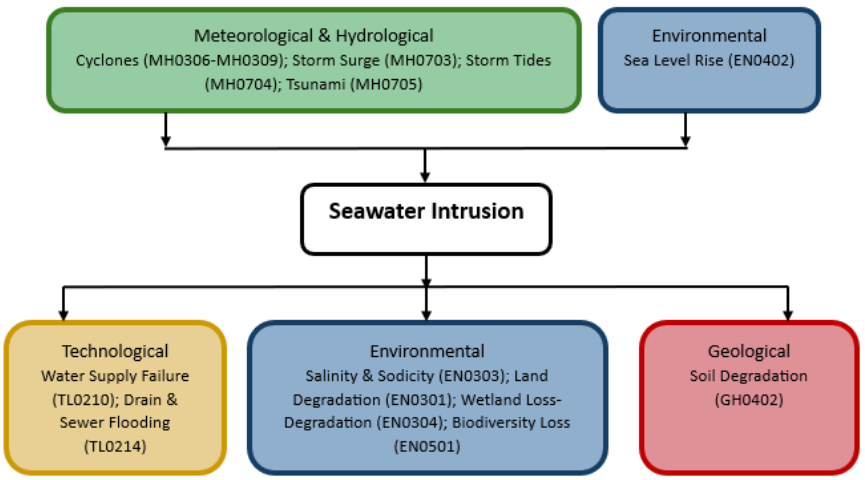
Seawater intrusion is also a threat to agriculture, both in coastal areas (U.S. Department of Agriculture Northeast Climate Hub, no date) and in regions where water supply and availability are limited, like Saudi Arabia (Benaafi et al., 2023). Saltwater is unsuitable for irrigation because of its elevated salinity, sodium and magnesium, resulting in salinity and alkalinity hazards that decrease with distance from the sea (Benaafi et al., 2023).

In addition to the elements cited above, seawater intrusion may also contaminate the aquifer with B, Se, F and Zn which were present above the permissible WHO standards. Other heavy metals were measured but at an acceptable level (Alshehri et al., 2021).

Saltwater can also impact water quality by 'unlocking' nutrients from fertilisers in farm fields. This is due to the unique chemistry of saltwater and how it interacts with soil. Once these nutrients become mobile, they can travel through networks of agricultural ditches into larger coastal water bodies such as tidal creeks and marshes. There, the excess nutrients can cause excess algae growth. When the algae die, they are broken down by bacteria. This process can use up all the oxygen in the water. Depleted oxygen levels can result in fish kills, loss of animal habitat, and other harmful effects on coastal ecosystems and wildlife (U.S. Department of Agriculture Northeast Climate Hub, no date). This is a threat to agriculture and environmental water uses.

In an urban context, seawater inclusion, making water saltier and more corrosive, damages pipes and other elements of the water supply and water drainage and sewer system. Other infrastructure like roads, bridges and buildings may also be damaged (Coastal City Resilience and Extreme Heat Action Project (CoCHAP), no date). During Hurricane Katrina in New Orleans in 2005, 90% of City Park was submerged in saltwater, leading to damages estimated at over $43 million (Williams, 2010).

Multi-hazard Context: The figure below summarises common interactions between seawater intrusion and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard contexts can be found in the 'Hazard drivers' and 'Impacts' sections above.



Preliminary – Corrections Pending

Monitoring: The section and the table below offer an overview of monitoring for seawater intrusion. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) disaster risk data/Information?	Water agencies, agriculture agencies, health agencies.
How is the hazard observed/monitored/forecast?	Measurement and monitoring of water levels in groundwater wells (Jasechko et al., 2020); hydrograph analysis; water quality sampling; and geophysical logging (California Water Science Center, no date).

Risk Management: Proper management of seawater intrusion issues requires good knowledge of aquifer systems and the ability to predict their future behaviour under different scenarios of naturally forcing and anthropogenic interactions. In this respect, numerical simulation is widely used to examine seawater intrusion in coastal aquifers and to evaluate alternative groundwater-resource-management scenarios (Jeen et al., 2021).

Management techniques are generally divided into two main types: managing the pumping of water from the groundwater aquifers and putting in place physical barriers to prevent saltwater from intruding into the aquifers (Wu et al., 2020). The table below provides a summary of strategies, approaches, and tools to mitigate the impacts of saltwater intrusion (Montanari, 2017; White and Kaplan, 2017).

Strategy	Approach	Tools
Modified water withdrawals	Optimise amounts, locations, and timing	Modelling and scenario analysis
	Water conservation	Irrigation efficiency improvement
		Rainwater harvesting
		Use reduction
Modified water deliveries	Optimise amounts, locations, and timing	Modelling and scenario analysis
	Enhance fresh groundwater recharge	Infiltration ponds/basins
		Land-use conversions
		Artificial recharge
Engineered structures	Direct freshwater	Diversions
	Impede saltwater	Saltwater barriers and other structures

As part of the Regional Adaptation Collaborative (RAC) of Natural Resources Canada, case studies have been developed in each of the Atlantic Canadian provinces in order to better understand saltwater intrusion, as well as the challenges and needs it presents. Case studies are being conducted to investigate existing conditions and the potential impacts of climate change on groundwater resources (Prince Edward Island Department of Environment, Labour and Justice, 2011).

Preliminary – Corrections Pending

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Coordinating agency or organisation

World Meteorological Organization (WMO).

Preliminary – Corrections Pending

EN0303 / ENVIRONMENTAL / Environmental Degradation

Salinity & Sodicity

Definition

Salt-affected soils consist of saline and sodic soils. Saline soils are those with an elevated amount of soluble salts, which reduces the ability of plants to take up water from soil due to the high osmotic pressure of the soil solution (FAO, 1985).

The technical criteria used to distinguish saline soil from other soils is the electrical conductivity (ECe) of a soil paste saturation extract: ECe > 2 dS/m (slightly saline) or ECe > 4 dS/m (saline) at 25 °C. The content of soluble salts should be higher than 0.1-0.2% (FAO, 2018). The threshold of salinity above which a plant will suffer deleterious effects varies according to plant species, type of ions in solution, soil health and soil fertility status.

Sodic soils get their name from sodium ions (Na^+) adsorbed on soil clays and organic matter. Sodic soils have elevated amounts of exchangeable Na^+ compared to the amounts of Ca^{2+} and Mg^{2+}, measured as sodium adsorption ratio (SAR) > 13 or exchangeable sodium percentage (ESP) > 15, and with relatively lower salinity (ECe < 4 dS/m at 25 °C). The SAR is a measure of how much sodium is in the water relative to Ca and Mg. Sodic soils have restricted aeration and water movement due to compacted soil structure and low porosity. The adsorbed Na^+ in sodic soils is hardly removed by natural processes and remains in soils for prolonged periods. Special measures are developed to reclaim such soils.

Preliminary – Corrections Pending

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Annotations

Synonyms

Salt-affected soils. Other names for sodic soil are: alkali soil, solonetz, and dispersive soil.

Additional scientific description

Salt-affected soils occur on all continents and under almost all climatic conditions, but their distribution is more extensive in arid

and semi-arid regions compared to humid regions. Soil salinisation and sodification are major soil degradation processes threatening ecosystems and are recognised as among the most important global problems for agricultural production, food security and sustainability in arid and semi-arid regions.

The global distribution of salt-affected soils has been reported at about 1 billion ha (Abrol, Yadav and Massoud, 1988; Szabolcs, 1989; Wicke et al., 2011). The latest estimates report the total area of salt-affected soils worldwide as 1,381 million ha, or 10.7% of the total land area (FAO, 2024).

Natural saline ecosystems–such as mangroves, salt marshes and coastal salt marshes–have suffered reductions, transformations and destruction. Due to their high environmental value, increasing efforts are being made for their conservation and restoration.

Natural saline environments possess specific plants called halophytes and contribute to global soil systems. They have suffered degradation, but due to their environmental value, they should be protected and restoration efforts are ongoing.

Salt-affected soils have serious impacts on soil functions, leading to consequences including reduced agricultural productivity, degradation of groundwater quality, loss of soil biodiversity and increased soil erosion. Salt-affected soils differ in micronutrient composition (Mohiuddin et al., 2022) and may have a reduced capacity to buffer or filter pollutants. Degradation of soil structure and disruption of ecological functions such as hydrological, nutrient and biogeochemical cycles impair the provision of ecosystem services critical for supporting human life and biodiversity.

Salt-affected soils reduce both the ability of crops to take up water and the availability of micronutrients. They also concentrate ions toxic to plants and may degrade the soil structure (FAO, 2020a).

Soluble salts most commonly present are chlorides and sulphates of sodium, calcium and magnesium. Nitrates are rarely present in appreciable quantities. Sodium and chloride are the dominant ions in highly saline soils, although calcium and magnesium are usually present in sufficient quantities to meet crop nutritional needs. Many saline soils also contain appreciable quantities of gypsum ($CaSO_4 \cdot 2H_2O$) in the profile (FAO, 1988).

Metrics and numeric limits

The technical criteria used to distinguish saline soil from other soils is the electrical conductivity of a soil paste saturation extract: ECe > 2 dS/m (slightly saline) or ECe > 4 dS/m (saline) at 25 °C. The content of soluble salts should be higher than 0.1-0.2% (FAO, 2018).

Sodic soils have elevated exchangeable Na^+ compared to Ca^{2+} and Mg^{2+}, measured as SAR > 13 or ESP > 15, but with relatively lower salinity (ECe < 4 dS/m at 25 °C). When desorbed by cation exchange, Na^+ can produce alkaline conditions, leading to clay dispersion that negatively affects soil structure and porosity. Saline soils with high ECe do not suffer from clay dispersion and their structure is stable.

Soil salinity and sodicity classes and crop growth (FAO, 1988):

Soil salinity class	Electrical conductivity of the saturation extract, dS/m	Effect on crop plants
Non saline	0-2	Negligible salinity effects
Slightly saline	2-4	Yields of sensitive crops may be restricted
Moderately saline	4-8	Yields of many crops are restricted
Strongly saline	8-16	Only tolerant crops yield satisfactorily
Very strongly saline	>16	Only a few very tolerant crops yield satisfactorily

Sodicity hazard	ESP, %
None	<15
Slight	15-30
Moderate	30-50
High	50-70
Extreme	>70

Key relevant UN convention/multilateral treaty

Food and Agriculture Organization of the United Nations Global Soil Partnership (GSP) (FAO, 2012).

Food and Agriculture Organization of the United Nations International Network of Salt-Affected Soils (INSAS) (FAO, 2019)

Preliminary – Corrections Pending

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Salt that accumulates in soil can come from a number of sources (NSW Department of Planning, Industry and Environment, 2019):

- Rainfall: airborne salts from ocean spray and pollution are dissolved in atmospheric moisture and deposited on the land in precipitation.
- Weathering: minerals that make up rocks break down and release ions that are able to form salts
- Aeolian deposits: wind picks up and transports dust and salt from soil and lake surfaces and redistributes it across the landscape.
- Connate salt: during deposition, salt has been incorporated into marine sediments, or in areas of internal drainage, salt has accumulated over geological time due to transport and evaporative processes. These areas may later become sources of salt.
- Irrigation water: marine storms, aquifers marine intrusion.

At present, increased primary (natural) soil salinization and sodification may be observed as the result of the following environmental factors: climate change and related phenomena (increasing aridity and freshwater scarcity, growing salinization of surface and groundwater, or permafrost thawing), increasing sea level rise, and tsunamis.

Increased secondary (human-induced) soil salinization and sodification may result from the following factors:

- Irrigation with poor quality water;
- Inadequate drainage or irrigation methods;
- Deforestation and removal of deep-rooted vegetation (dryland salinization);
- Excessive water pumping in coastal and inland areas;
- Overuse of fertilizers;
- Use of de-icing agents; and
- Mining activity.

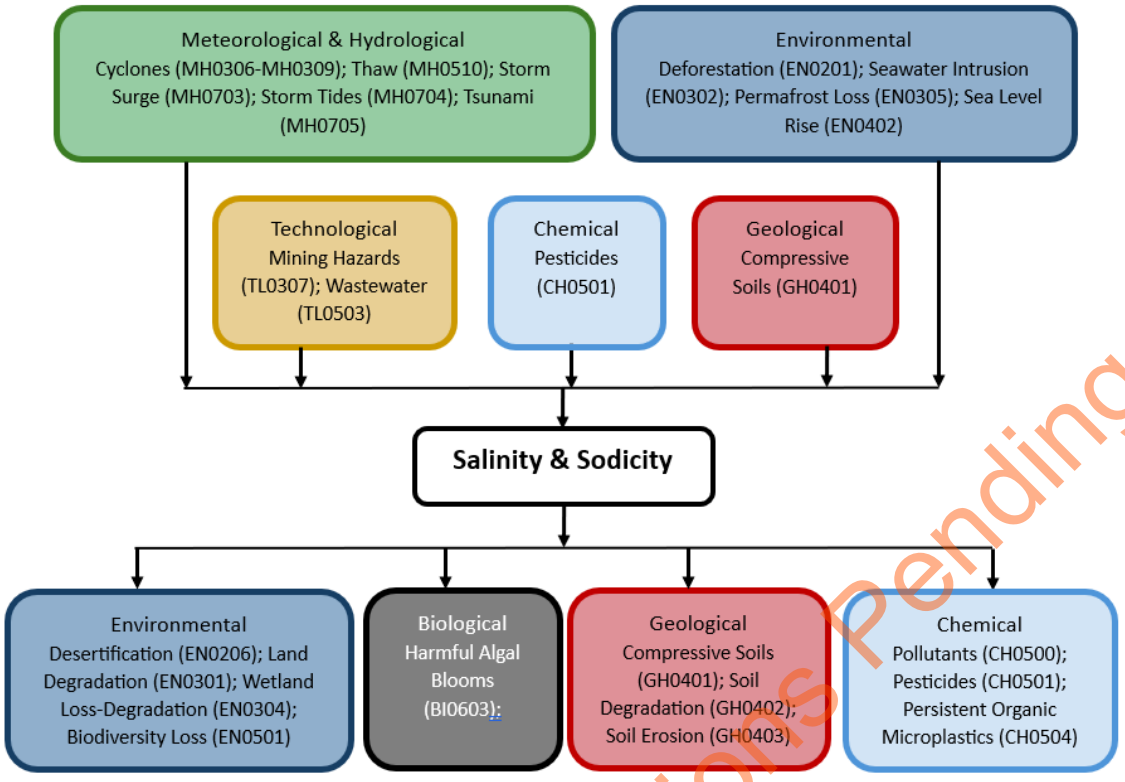
Impacts: Salinity has different impacts (NSW Department of Planning, Industry and Environment 2019):

- Farms: salinity can decrease plant growth and water quality resulting in lower crop yields and degraded stock water supplies. Excess salt affects overall soil health, reducing productivity. It kills plants that are not adapted to salinity, leaving bare soil that is prone to erosion. Sodicity affects soil structure leading to decreased permeability of soils and waterlogging.
- Wetlands: as salinity increases over time, wetlands become degraded, endangering wetland species and decreasing biodiversity. Where sulphate salts are present, there is an increased risk of acid sulphate soil formation if reducing conditions prevail and no calcium carbonate ($CaCO_3$) is present within the soil matrix.
- Rivers: increased volume (load) and/or concentration (electrical conductivity) of salinity in creeks and streams degrades urban water supplies, affects irrigated agriculture and horticulture, and adversely impacts on riverine ecosystems.
- Drinking water: when a source of drinking water becomes more saline, extensive and expensive treatment may be needed to keep salinity at levels suitable for human use.
- Buildings, roads and pipes: salinity damages infrastructure, shortening its life and increasing maintenance costs.
- Sport grounds: salty ground may lose all grass cover, making playing fields unusable.

The increasing use of wastewaters for irrigation of agricultural fields lead to the occurrence of “emerging pollutants” (microplastics, pharmaceuticals, drugs, and organic pollutants) in waters, soils and crops (Sayed et al., 2024). This contributes to a multi-hazard situation affecting soil health, biodiversity and human nutrition that should be considered when planning the water use (Estévez et al., 2012).

Multi-hazard Context: The figure below summarises common interactions between salinity & sodicity and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the ‘Hazard drivers’ and ‘Impacts’ sections above.

Preliminary – Corrections Pending



Preliminary – Corrections Pending

Monitoring: Soil and water salinity/sodicity monitoring at the inland areas at risk and the whole coastal area is a way to take actions when the salinity and sodicity levels start to increase.

Comprehensive data on the extent of salt-affected soils and soils at risk of salinization are lacking worldwide, with many countries lacking official data or experiencing conflicting results from existing data. Improving mapping techniques and transitioning to digital tools are essential steps to enhance monitoring and management efforts. Moreover, harmonizing data collection methods and developing conversion equations (pedotransfer functions) are crucial for the accurate assessment of soil salinity and sodicity.

Given the already high levels of saline groundwater and the widespread use of brackish water for irrigation, urgent measures are needed to prevent further salinization caused by droughts and excessive aquifer exploitation. Establishing robust irrigation water monitoring systems is essential to ensure the sustainable utilization of water resources and mitigate salinity-related challenges. Additionally, efforts to enhance water quality monitoring must be intensified, considering the significant proportion of poor-quality water bodies globally. Prioritizing the improvement of irrigation water quality – especially in arid regions where salinity and sodicity pose significant threats to agricultural productivity – is crucial for sustainable water management.

Risk Management: Both mitigation and adaptation strategies can be applied to sustainably manage salt-affected soils for agricultural production. Mitigation strategies are aimed at the reduction of salinity levels in the root zone and include physical, chemical and biological measures.

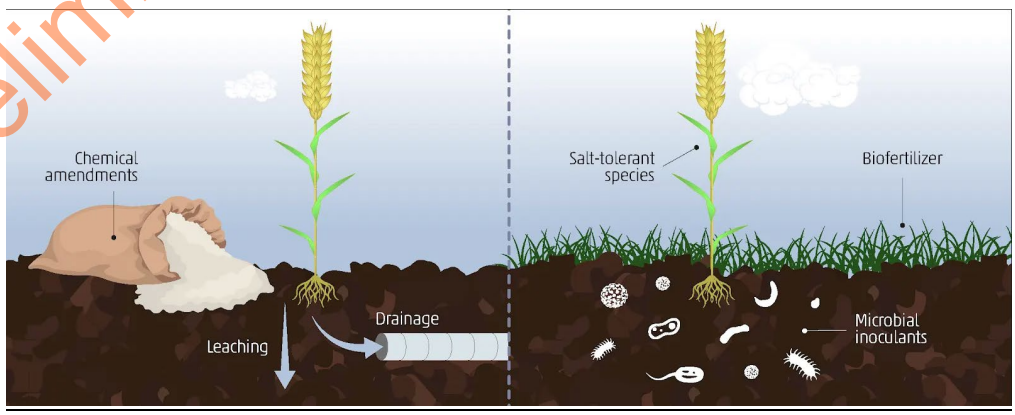


Figure 1: Examples of mitigation (left) and adaptation (right) strategies. Source *FAO. 2024. Global status of salt-affected soils – Main report. Rome.* https://doi.org/10.4060/cd3044en

Physical mitigation measures include mulches, interlayers from loose materials, leaching, drainage, surface scraping, compost and plant residue incorporation, biochar, low rank coal, deep tillage, land shaping and land levelling.

Biological mitigation measures include adjustment of planting time and place; crop system management (improved crop rotation,

agrobiodiversity, crop system diversification); agroforestry; and bioremediation.

Chemical remediation measures include adding gypsum and other calcium containing amendments to affected soils.

Adaptation strategies aim at coping with existing salinity levels. They include breeding of salt-tolerant crops; domestication of halophytes and other non-conventional crops.

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Coordinating agency or organisation

Food and Agricultural Organization of the United Nations.

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EN0304 / ENVIRONMENTAL / Environmental Degradation

Wetland Loss/Degradation

Definition

Wetland loss/degradation is a negative trend in wetland condition, caused by physical or direct/indirect human-induced processes, expressed as a long-term reduction or loss of at least one of the following: biological productivity, ecological role or value to humans (Olsson et al., 2019). Wetlands are defined as areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres (Convention on Wetlands, 1971: Article 1.1). Wetlands may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six metres at low tide lying within the wetlands (Convention on Wetlands, 1971: Article 2.1).

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Annotations

Synonyms

Vlei.

Additional scientific description

The Convention classification of wetland types includes 42 types of wetlands grouped into three categories: marine and coastal wetlands, inland wetlands, and human-made wetlands. The five major wetland types are generally recognised as: marine (coastal wetlands including coastal lagoons, rocky shores, and coral reefs); estuarine (including deltas, tidal marshes, and mangrove swamps); lacustrine (wetlands associated with lakes); riverine (wetlands along rivers and streams); and palustrine (meaning 'marshy' – marshes, swamps and bogs). In addition, there are human-made wetlands such as fish and shrimp ponds, farm ponds, irrigated agricultural land, salt pans, reservoirs, gravel pits, sewage farms and canals (Convention on Wetlands 1971; Recommendation 4.7; Resolution VI.5 and Resolution VII.11).

Conversion of freshwater wetlands to agricultural land has historically been a common way of increasing the area of arable land (Olsson et al., 2019; Fluet-Chouinard et al., 2023). However, wetlands with organic and wet soils are crucial in maintaining the Earth's carbon balance as they contain soils with high organic carbon content. Human activities on wetlands (e.g. drainage, agriculture, forestry, peat extraction, aquaculture) and their effects (e.g. oxidation of soil organic matter) may significantly affect the carbon and

nitrogen balance and, thus, the greenhouse gas emissions from these lands. The degradation of peatland ecosystems, for example, is particularly relevant in the context of climate change given their very high carbon storage and their sensitivity to changes in soils, hydrology and/or vegetation. Human activity, either draining or mining, takes up approximately 10% of global peatlands, releasing 80.8 Gt carbon and 2.3 Gt nitrogen. This corresponds to an annual greenhouse gas emission of 1.91 (0.31–3.38) Gt CO_2-equivalent that could be saved with peatland restoration. Drainage induces peatland degradation and alters peatlands, globally, from a net sink to a net source of greenhouse gases in the land-use sector (Joosten, 2009; IPCC, 2014; Leifeld and Menichetti, 2018; Olsson et al., 2019; Loisel et al., 2022; Strack et al., 2022; UNEP, 2022).

Wetlands constitute a resource of great economic, cultural, scientific and recreational value to human life by providing provisioning, regulating and supporting ecosystem services (Reed et al., 2019). Wetlands and people are ultimately interdependent. Furthermore, wetlands are an essential component of the global water cycle and play a key role in climate regulation. As such, the progressive encroachment on and loss of wetlands needs to be stopped, and measures must be taken to conserve and make wise use of wetland resources. Achieving this at a global level requires cooperative, intergovernmental action. The Convention on Wetlands provides the framework for such international, national and local action (Convention on Wetlands, 2016).

Metrics and numeric limits

Approximately 1% of the Earth's surface is freshwater wetlands. They provide a large number of ecosystem services such as groundwater replenishment, flood protection and nutrient retention, and are biodiversity hotspots. Over two-thirds of the world's fish harvest is linked to the health of coastal and inland wetland areas. Agriculture is also impacted by wetlands through the maintenance of water tables and nutrient retention in floodplains. In addition, rice, a common wetland plant, is the staple diet of more than half of the global population. The global loss of wetlands has recently been estimated at 21% since the 1700s; however, there are significant regional differences (Fluet-Chouinard et al., 2023).

Coastal wetlands around the world are sensitive to sea level rise. Studies and projections of the impacts on global coastlines are inconclusive, with suggestions that between 0% and 90% (depending on sea level rise scenario) of present-day wetlands will disappear during the 21st century (Olsson et al., 2019).

Despite their importance, coastal wetlands are listed among the most heavily damaged natural ecosystems worldwide; this includes damage to mangrove ecosystems (Bunting et al., 2022). However, coastal wetland restoration and preservation is a highly cost-effective strategy for society. For example, the preservation of coastal wetlands in the USA provides storm protection services worth USD 23.2 billion per year. Coastal wetlands function as valuable, self-maintaining 'horizontal levees' for storm protection (Costanza et al., 2008; Olsson et al., 2019).

Globally, approximately 1.1 Gha of land is affected by salt, with 14% of this categorised as forest, wetland or some other form of protected area (Olsson et al., 2019).

Key relevant UN convention / multilateral treaty

The Convention on Wetlands is an intergovernmental treaty whose mission is the conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world (Convention on Wetlands, 2016). As of August 2023, 172 nations had joined the Convention as Contracting Parties, and more than 2,400 wetlands of international importance, covering over 2.5 million km², have been designated for inclusion in the List of Wetlands of International Importance.

The United Nations Educational, Scientific and Cultural Organization (UNESCO) serves as the depositary for the Convention. However, the Convention on Wetlands is not part of the United Nations or UNESCO system of environmental conventions and agreements. The Convention is responsible only to its Conference of the Contracting Parties (COP), and its day-to-day administration has been entrusted to a secretariat under the authority of a standing committee elected by the COP. The Secretariat to the Convention on Wetlands is hosted under contract by the International Union for Conservation of Nature (IUCN) in Gland, Switzerland (Convention on Wetlands, 2016). The Convention is also co-custodian for SDG indicator 6.6.1.

Examples of hazard drivers, impact and risk management

Hazard Drivers: Overexploitation of freshwater resources jeopardises human wellbeing and the environment. Wetlands, critical ecosystems for biodiversity, water purification and flood control, are increasingly under threat from a complex interplay of socio-economic and environmental hazards. The multi-hazard context of wetland loss and degradation involves a combination of natural and anthropogenic factors that exacerbate their vulnerability.

Human activities are a primary driver of wetland loss, in particular land use change and agriculture. Agricultural expansion results in direct habitat loss and fragmentation. Agricultural practices represent a significant driver of wetland loss, primarily through conversion for agricultural land, water extraction and pollution. The expansion of agricultural land often necessitates the drainage and infilling of wetlands, disrupting their natural hydrology and ecological functions. Furthermore, agricultural activities can lead to increased nutrient pollution, sedimentation and habitat fragmentation, further degrading wetland ecosystems. These impacts can have severe consequences for biodiversity, water quality and the provision of ecosystem services (Convention on Wetlands, 2022).

Climate change also contributes to wetland loss, manifesting through rising temperatures, altered precipitation patterns and increased

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frequency of extreme weather events such as storms and droughts. These climatic shifts disrupt hydrological regimes, leading to either prolonged inundation or excessive drying, both detrimental to wetland health. For instance, intensified storms can cause physical damage and increase sedimentation rates, while droughts can reduce water availability, impacting the flora and fauna dependent on wetland habitats (Humpenöder et al., 2020; Gitay et al., 2011).

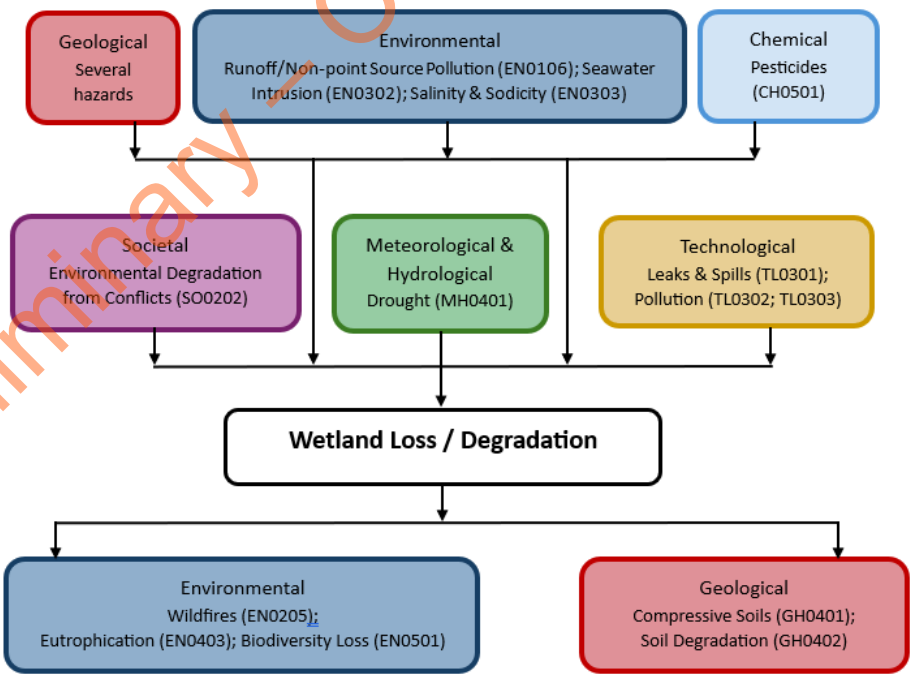
Moreover, socio-economic factors such as poverty and inadequate environmental governance can exacerbate wetland degradation. In many regions, wetlands are exploited for their resources–such as timber, fish and water–without sustainable management practices, leading to over-extraction and habitat destruction (Ghosh et al., 2023).

Impacts: Access to safe water, human health, food production, economic development and geopolitical stability are made less secure by the degradation of wetlands driven by the rapidly widening gap between water demand and supply. Even with current attempts to maintain minimum water flows for ecosystems, the capacity of wetlands to continue to deliver benefits to people and biodiversity–including clean and reliable water supplies–is declining. Efforts to support water allocation to ecosystems, such as environmental flow requirements, placing upper limits on water allocations and new water management legislation, must be strengthened (Convention on Wetlands, 2016).

Wetland loss/degradation results in associated reductions in ecosystem services delivered by wetlands, such as: provisioning services including food and freshwater; regulating services such as flood control, storm protection, drought buffering, groundwater recharge and discharge, and carbon sequestration; cultural services such as recreation; and supporting services such as purification of water supplies, shoreline stabilisation and erosion control, retention of nutrients, sediments and pollutants, and stabilisation of local climate conditions–particularly rainfall and temperature. The ecosystem services related to human health primarily cover the supply of water, food, nutrition and medicine; purification of waste products; and buffering against adverse flooding and climate effects (Convention on Wetlands, 2005; 2016).

The cumulative effects of these hazards create a feedback loop, where the degradation of wetlands reduces their resilience to future threats, thereby increasing their susceptibility to ongoing environmental changes. Addressing this multi-hazard context requires integrated management approaches that consider the interconnections between climatic, environmental and socio-economic factors to protect and restore these vital ecosystems (Convention on Wetlands, 2012; Docherty et al., 2020).

Multi-hazard Context: The figure below summarises common interactions between wetland loss or degradation and other hazards. This information should be used with caution and not be solely relied upon in disaster risk management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below provide an overview of monitoring for wetland loss or degradation. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency or authority responsible for disaster management.

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Which institution(s) produce(s) disaster risk data/information?	Environmental agencies; water agencies
How is the hazard observed/monitored/forecast?	Traditional monitoring methods include water quality assessments and biodiversity surveys. Satellite imagery is crucial for large-scale monitoring of wetland extent, vegetation cover and hydrological patterns (Rebelo et al., 2018). Changes in these parameters can serve as early indicators of wetland degradation. For instance, a decline in vegetation cover or alterations in water bodies might signal hydrological changes impacting wetland health (Demarquet et al., 2023; Rebelo et al., 2018; Lowry, 2006; van Dam et al., 1998). Biogeochemical indicators—such as nutrient levels, organic matter content and sediment accumulation—can also offer valuable insights into wetland condition. These parameters can be monitored through regular water quality assessments and sediment core analysis (Reddy et al., 2022).

Risk Management: Preserving wetlands requires an integrated approach, which not only addresses wetland conservation and restoration but also the implementation of effective climate change solutions and the achievement of the Sustainable Development Goals. This is particularly important given that water-related hazards constitute around 74% of all natural hazards (Chen, 2022; UNESCO 2020; Priscoli et al., 2015). Many Contracting Parties to the Convention on Wetlands, recognising the importance of the conservation and wise use of wetlands, have adopted some form of an avoid-mitigate-compensate approach to wetland loss and degradation. In this context, national, regional, and local laws and policies emphasise that negative wetland impacts should be avoided if at all possible. If such negative impacts cannot be avoided or prevented, actions should be taken to mitigate (minimise or reduce) this wetland loss or degradation. Finally, if wetland loss or degradation remains after such mitigation, actions should be taken to compensate for (i.e., offset) these residual impacts (Gardner et al., 2012).

Wetlands themselves can act as early warning systems for broader catchment changes. Alterations in wetland hydrology, such as changes in water levels or flow regimes, can signal broader hydrological shifts that may impact water resources and downstream ecosystems (Grenfell et al., 2005).

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Coordinating agency or organisation

Convention on Wetlands of International Importance Especially as Waterfowl Habitat.

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EN0305 / ENVIRONMENTAL / Environmental Degradation

Permafrost Loss

Definition

Permafrost is defined as ground that remains frozen at or below 0°C for a minimum of two consecutive years. Permafrost loss, also known as permafrost thaw, is the progressive loss of ground ice in permafrost, usually due to input of heat. Thaw can occur over decades to centuries over the entire depth of permafrost ground, with impacts occurring while thaw progresses. During thaw, temperature fluctuations are subdued because energy is transferred by phase change between ice and water. After the transition from permafrost to non-permafrost, ground can be described as thawed (IPCC, 2019).

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Annotations

Synonyms

Permafrost degradation, Permafrost thaw

Additional scientific description

Permafrost includes the mineral part of the ground (rocks) as well as any organic matter and ice if it is present (IPCC, 2019). The active layer is the uppermost part of permafrost, which thaws during summer and re-freezes during winter.

Permafrost currently covers around 15 million km², or approximately 15% of the land in the Northern Hemisphere, mostly in the Arctic region, and is very sensitive to climate change (Obu, 2021). An additional 2.5 million km² of permafrost also exists below the seabed in the Arctic continental shelves (Overduin et al., 2019; Obu, 2021).

Gradual permafrost loss or thaw is a steady but slow process, impacting the soil and related to a general increase in the temperature of the ground. Ground temperatures are monitored by the Global Terrestrial Network for Permafrost by examining temperature profiles from multiple borehole sites across the permafrost regions (Biskaborn et al., 2015; 2019). During 2007-2016, continuous-zone permafrost temperatures in the Arctic and Antarctic increased by 0.39 ± 0.15°C and 0.37 ± 0.10°C respectively, and at some locations, the temperature is 2-3°C higher than 30 years ago (Biskaborn et al., 2019).

Abrupt thaw happens mainly in regions with excess ice and occurs when the land surface collapses because of the ice melting away, resulting in, for example, thaw slumps, active layer detachments or thermokarst lakes. This can affect many metres of permafrost soil in the period of a few days to years and will impact the hydrological state of the permafrost (Turetsky et al., 2020). It is estimated that 20-39% of the northern permafrost region is covered by ice-rich thermokarst landscapes (Nitzbon et al., 2024; Olefeldt et al., 2016). Carbon emissions released by abrupt thaw are not currently well represented by models (Turetsky et al., 2020); however, it should be noted that new evidence also indicates that positive feedback on the climate from GHG emissions related to permafrost thaw would not cause enough additional thaw and corresponding GHG emissions to drive a self-perpetuating feedback cycle that would lead to rapid and global-scale permafrost loss once initiated (Nitzbon et al., 2024).

Under future climate change scenarios, the Coupled Model Intercomparison Project Phase 6 (CMIP6) models project a gradual loss of permafrost of between 0.3 and 3.4 million km² per °C increase in global surface air temperature (5th to 95th percentile; Burke et al., 2020). This is equivalent to a reduction of between 10% and 40% per °C in the annual mean frozen volume in the top 2 metres of soil. These estimates are slightly lower than the 4.0 [-1.1; +1.0] million km² per °C equilibrium sensitivity projected by Chadburn et al. (2017),

who derived this using an observational-based relationship.

The permafrost region represents a large, climate-sensitive reservoir of organic carbon, with approximately twice as much carbon in the soil as is currently contained in the Earth's atmosphere. The top 3 metres of permafrost soils contain 1,035 ± 150 Pg C (Tarnocai et al., 2009; Hugelius et al., 2014) and could become vulnerable to decomposition due to climate warming. Schuur et al. (2015) suggested that between 5% and 15% of this permafrost carbon pool may be decayed and released as either carbon dioxide or methane during the 21st century, contributing to further global warming. Some researchers postulate that this feedback could cause an additional warming of between 0.2% and 12% of the change in global temperature by 2100 (Burke et al., 2017), given that about half of below-ground carbon is stored in thermokarst landscapes that are vulnerable to abrupt thaw (Olefeldt et al., 2016) and the release of this additional carbon has not been considered in these estimates. Therefore, these estimates may be a substantial underestimation of carbon emissions from thawing permafrost (Turetsky et al., 2020). On the other hand, other researchers indicate that there is no proof that permafrost thaw is self-amplifying; rather, that the effect is local, or possibly regional, and that thawing will continue in step with climate warming (Nitzbon et al., 2024).

Metrics and numeric limits

The Global Terrestrial Network for Permafrost (GTN-P; Streletskiy et al., 2017) coordinates long-term monitoring of the thermal state of permafrost via an extensive borehole network used to measure ground temperatures at depths from the surface to up to 100 m. It also coordinates monitoring of the maximum active layer thickness via the Circumpolar Active Layer Monitoring (CALM) programme (no date). Typically, this is done at the end of summer on a grid arrangement via mechanical probing of the soil. Currently, it is not possible to use Earth observation data for routine permafrost monitoring; however, the Arctic Landscape Explorer (ALEX), attempts to monitor relevant proxies like lake formation and coastal erosion (Lübker et al., 2024).

Key relevant UN convention/multilateral treaty

The UN Climate Change Paris Agreement (2015) builds upon the United Nations Framework Convention on Climate Change and, for the first time, brings all nations into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects, with enhanced support to assist low- and middle-income countries to do so. As such, it charts a new course in the global climate effort.

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Permafrost thaw is one of the leading factors increasing climate-related vulnerability (Murray et al., 2012). Changes in temperature and precipitation typically act as gradual (i.e. continuous) disturbances that directly affect permafrost by modifying the ground thermal regime. Climate warming can also modify the occurrence and magnitude of abrupt physical disturbances such as fire (Wotton et al., 2017), and soil subsidence and erosion resulting from ice-rich permafrost thaw (Lewkowicz and Way, 2019). These 'pulse' (i.e. discrete) disturbances are often part of the ongoing disturbance and successional cycle in Arctic and boreal ecosystems (Grosse et al., 2011), but changing rates of occurrence have recently been observed, altering the landscape distribution of successional ecosystem states (Farquharson et al., 2019).

Recent climate warming has been linked to increased wildfire activity in boreal forest regions in Alaska and western Canada (Gillett et al., 2004; Veraverbeke et al., 2017). Based on satellite imagery, an estimated 80,000 km² of boreal area was burned globally per year from 1997 to 2011 (Giglio et al., 2013). During the summers of 2019 and 2020, the Arctic saw record wildfires, mainly in Siberia in areas underlain by permafrost peatland. There is high confidence that fire will accelerate change in permafrost relative to climate effects alone, if the rates of these disturbances increase. The observed trend of increasing fire is projected to continue for the rest of the 21st century across most of the tundra and boreal region under many climate scenarios (Meredith et al., 2019).

Impacts: Permafrost thaw can lead to ground subsidence–a process where the ground surface collapses due to the loss of underlying support. This can cause serious damage to infrastructure (e.g. roads, runways, buildings), with variable effects across infrastructure types. Disrupted transportation networks and threatened communities are among the potential consequences (Bastedo, 2007; GRID-Arendal, 2023). Impacts on infrastructure affect the health, economic livelihood and safety of communities. For example, in northern Canada, adapting or repairing infrastructure may cost several million to many billions of dollars, depending on damage extent and infrastructure type. The Tibbitt to Contwoyto winter road (Northwest Territories, Canada) experienced climate-related closures in 2006, remaining open for only 42 days compared to 76 in 2005 (Bastedo, 2007). Residents and businesses had to airlift supplies, costing millions of dollars.

In the Northwest Territories, 10% of public access buildings have been retrofitted since 2004 due to critical structural malfunctions. In Inuvik, a local school experienced a complete roof collapse under heavy snowfall. As permafrost continues to thaw and structural integrity declines, snow loads may increasingly cause collapses (Bastedo, 2007; Murray et al., 2012). These rapid changes challenge planners, decision-makers and engineers, threatening infrastructure stability and functionality (Meredith et al., 2019). Climate and permafrost projections suggest a wide range of infrastructure is at risk (Melvin et al., 2017; Schneider von Deimling et al., 2020). A circumpolar study found that around 70% of infrastructure–including over 1,200 settlements (about 40 with populations over 5,000)–is located in areas where permafrost is projected to thaw by 2050 under RCP4.5 (Hjort et al., 2018).

The geopolitical landscape of the Arctic is also affected. As permafrost thaws, previously inaccessible resources (e.g. minerals, oil and gas) become more accessible, potentially escalating competition and geopolitical tensions (Marten, 2023; Kalhoro, 2022).

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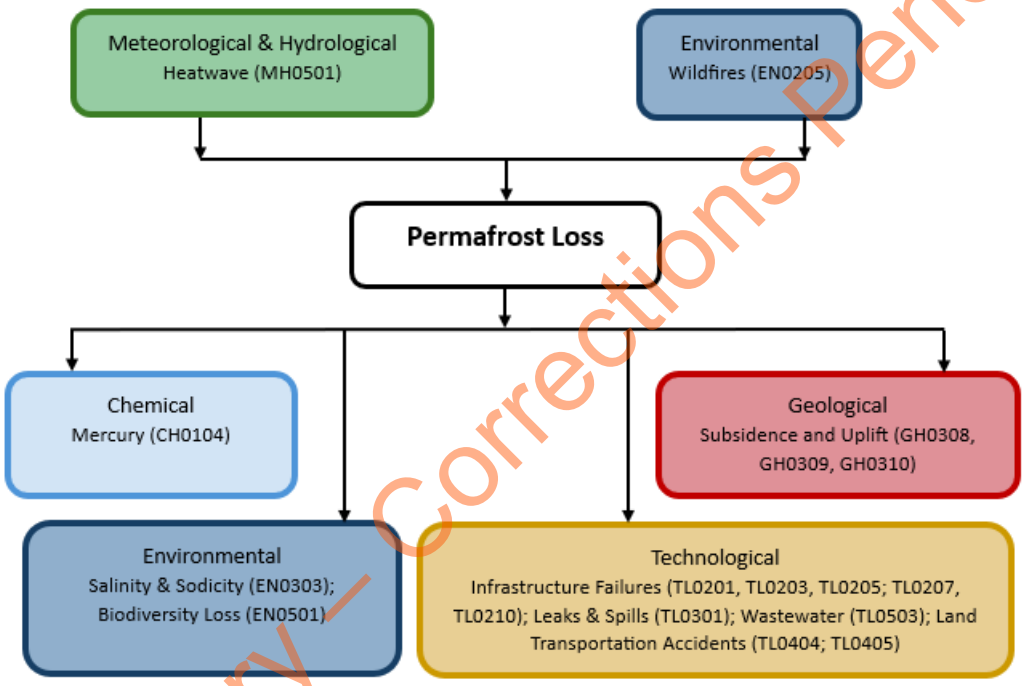
Freshwater quality and availability are also at risk. Thaw alters drainage patterns and contaminates water with carbon compounds, pathogens and pollutants such as mercury and lead (Rudnicka-Kępa and Zaborska, 2021; Schuster et al., 2018; Charlier et al., 2020; Christie, 2021). Disruption of meltwater-dependent ecosystems may also lead to biodiversity loss (Rani et al., 2021).

Permafrost loss also alters ecosystems. For example, the ecology of thaw-impacted lakes and streams is likely to change, with microbiological communities adapting to changes in sediment, dissolved organic matter and nutrient levels (Vonk et al., 2015).

Another primary concern associated with permafrost loss is the release of greenhouse gases. Permafrost acts as a large natural carbon sink, storing immense quantities of methane and carbon dioxide. As permafrost thaws, these potent greenhouse gases may be released into the atmosphere, accelerating climate change and further warming the planet. This may create a dangerous feedback loop, where rising temperatures drive permafrost thaw, which in turn releases more greenhouse gases, perpetuating the cycle (Turetsky et al., 2020). However, some researchers argue that this may not occur (Nitzbon et al., 2024).

Multi-hazard Context: The figure below summarises common interactions between permafrost loss and other hazards. This information should be used with caution and not relied on solely for disaster risk management, as not all interactions may be included. Note that hazards occurring simultaneously or locally may not be causally linked. Specific multi-hazard examples appear in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below provide an overview of monitoring for permafrost loss. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency or authority responsible for disaster management.

Which institution(s) produce(s) disaster risk data/information?	No information available
How is the hazard observed/monitored/forecast?	Ground-based measurements, such as temperature sensors at various permafrost depths, provide direct indicators of thermal regime changes. Surface deformation, monitored through techniques such as LiDAR and Interferometric Synthetic Aperture Radar (InSAR), can provide high-resolution topographic data and detect subtle ground movements associated with permafrost thaw and subsidence (Zhang et al., 2022). Remote sensing, using satellite imagery, offers a synoptic perspective on permafrost conditions, enabling the tracking of vegetation changes, hydrological alterations and landscape evolution (Lübker et al., 2024). Borehole measurements of active layer thickness also offer valuable ground-truth data (Biskaborn et al., 2019). Additionally, Global Positioning System (GPS) monitoring of infrastructure can detect early signs of ground instability due to permafrost degradation (Zhang et al., 2020).

Risk Management: Reducing and avoiding infrastructure impacts from climate change requires attention to engineering, land use planning, maintenance, culture, and budgeting. In some cases, relocating human settlements may be necessary (Meredith et al., 2019). Subsidence due to thawing permafrost and river and delta erosion makes coastal and rural communities in Alaska and Russia particularly vulnerable, potentially requiring relocation in the future (Romero Manrique et al., 2018).

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Coordinating agency or organisation

Not identified.

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EN0401 / ENVIRONMENTAL / Environmental Degradation

Ocean Acidification

Definition

Ocean acidification refers to a reduction in the pH of the ocean over an extended period, caused primarily by the uptake of carbon dioxide from the atmosphere. It can also result from other chemical additions to or subtractions from the ocean (IPCC, 2011).

Reference

IPCC, 2011. IPCC Workshop on Impacts of Ocean Acidification on Marine Biology and Ecosystems. Intergovernmental Panel on Climate Change (IPCC). Available at: https://archive.ipcc.ch/pdf/supporting-material/IPCC_IAOMBE_WorkshopReport_Japan.pdf (Accessed 12 February 2025).

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Annotations

Synonyms

Not available.

Additional scientific description

The ocean absorbs approximately 30% of the carbon dioxide (CO_2) released into the atmosphere from human activities. As CO_2 dissolves in seawater, it alters the carbonate chemistry, causing a reduction in pH, a decrease in dissolved carbonate ion concentration, an increase in the partial pressure of CO_2 (pCO_2), and a rise in the concentration of dissolved bicarbonate ions (IPCC, 2019; UNESCO, 2023).

When CO_2 is absorbed by seawater, a series of chemical reactions increase the concentration of hydrogen ions. This increase causes seawater to become more acidic and reduces the availability of carbonate ions.

Carbonate ions are essential building blocks for structures such as seashells and coral skeletons. A reduction in carbonate ions makes it more difficult for calcifying organisms–such as oysters, clams, sea urchins, shallow-water corals, deep-sea corals and calcareous plankton–to build and maintain shells and calcium carbonate structures.

These chemical changes can also affect the behaviour of non-calcifying organisms. For example, some fish may experience reduced ability to detect predators in more acidic waters. As these organisms become at risk, entire marine food webs may also be affected.

Ocean acidification is impacting all of the world's oceans, including coastal estuaries and waterways. Many economies depend on fisheries and shellfish, and a significant portion of the global population relies on the ocean as a primary source of protein (NOAA, 2024).

Metrics and numeric limits

The seawater carbon system has four measurable variables, and at least two of these are needed in order to constrain the carbon system relative to ocean acidification: pH, partial pressure of carbon dioxide (pCO_2), total alkalinity (TA), and total dissolved inorganic carbon (DIC).

Temperature and salinity data are also required.

The units of these parameters are: pH (on the total scale); pCO_2 [µatm]; DIC [µmol/kg]; and TA [µmol/kg] (IOC, 2018; IPCC, 2019).

Key relevant UN convention / multilateral treaty

United Nations 2030 Agenda for Sustainable Development (UNGA, 2015)

United Nations Framework Convention on Climate Change (UNFCCC, 1994)

UNFCCC Paris Agreement (UNFCCC, 2015)

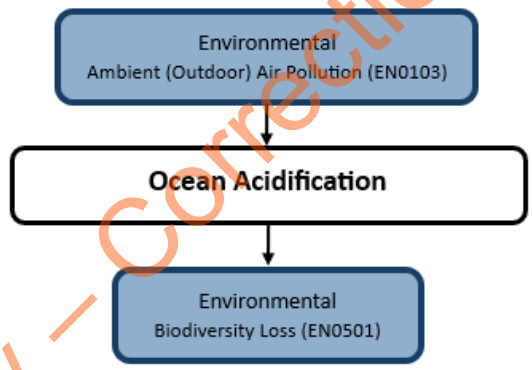
Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Ocean acidification occurs when carbon dioxide (CO_2) absorbed by the ocean reacts with seawater, resulting in a shift in dissolved carbonate chemistry, including increased acidity levels in the marine environment (i.e. decreased seawater pH).

Impacts: The observed changes have been shown to cause a range of responses at the organism level that can affect biodiversity and ecosystem structure. Direct consequences for marine life can propagate through the food web and affect ocean-related services and uses, including food security (in terms of fisheries and aquaculture), livelihoods, coastal protection, tourism and cultural heritage.

For example, decreases in dissolved carbonate ion concentrations have been shown to impact the growth and larval survival of key marine calcifying organisms, including oysters, mussels and corals. The impact on corals is likely to result in weaker reefs, making them more prone to storm damage and altering the structural complexity that supports biologically diverse reef ecosystems. Effects on growth, reproduction and predator avoidance have also been observed in many other marine organisms due to changes in pH and/or partial pressure of carbon dioxide (pCO_2). Food production from marine calcifiers in both wild and aquaculture fisheries is expected to be adversely affected by ocean acidification, with some aquaculture facilities already implementing monitoring and adaptation strategies.

Multi-hazard Context: The figure below summarises common interactions between ocean acidification and other hazards. This information should be used with caution and should not be solely relied upon in disaster risk management, particularly as some interactions may not have been included. Note that hazardous events occurring simultaneously or locally in space or time may not necessarily cause, amplify or be otherwise related to one another. Specific examples of the multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below provide an overview of monitoring for ocean acidification. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency or authority responsible for disaster management.

Which institution(s) produce(s) disaster risk data/information?	Global Ocean Acidification Observing Network (GOA-ON - https://goa-on.org/)
How is the hazard observed/monitored/forecast?	Remote sensing and satellite monitoring. The Ships of Opportunity Programme also monitors pH, CO_2 and temperature.

Risk Management: It may be possible to lessen the impacts of ocean acidification on ocean services through mitigation and adaptation strategies for carbon dioxide emissions. This would be informed by appropriate monitoring and improved understanding of natural and human-induced variability, as well as the rate of change, combined with studies of biological impacts. Further investigation is also required, as ocean acidification may act as a stress multiplier when combined with other changes in the marine environment, including changes in temperature and oxygen concentrations.

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Coordinating agency or organisation

United Nations Educational, Scientific and Cultural Organization (UNESCO) and the Intergovernmental Oceanographic Commission (IOC).

Preliminary – Corrections Pending

EN0402 / ENVIRONMENTAL / Environmental Degradation

Sea Level Rise

Definition

Sea-level change (sea-level rise / sea-level fall) refers to a change in the height of sea level, both globally and locally (relative sea-level change), at seasonal, annual, or longer time scales. It results from a change in ocean volume due to a change in the mass of water in the ocean (e.g. melting of glaciers and ice sheets), changes in ocean water density (e.g. expansion under warmer conditions), changes in the shape of ocean basins, changes in the Earth's gravitational and rotational fields, and local land subsidence or uplift (IPCC, 2019).

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Preliminary – Corrections Pending

Annotations

Synonyms

Not identified.

Additional scientific description

Global sea level, measured as the distance from the centre of the Earth to the surface of the ocean, is termed eustatic sea level (Rovere et al., 2016). Global mean sea-level change resulting from a change in the ocean's mass is termed barystatic. The amount of barystatic sea-level change due to the addition or removal of water mass is referred to as its sea-level equivalent (SLE). Sea-level changes caused by changes in water density are termed steric. Density changes due to temperature are called thermosteric, and those due to salinity are termed halosteric. Barystatic and steric changes exclude changes caused by ocean basin shape or redistribution of ocean mass (IPCC, 2019).

Global mean sea level rose by 0.20 m (0.15–0.25 m) between 1901 and 2018 (Fox-Kemper et al., 2021).

The rate of sea-level rise has increased since the late 1960s, averaging 2.3 mm [1.6 to 3.1 mm] yr^{-1} from 1971–2018, increasing to 3.7 mm [3.2 to 4.2 mm] yr^{-1} from 2006–2018 (Fox-Kemper et al., 2021).

The IPCC projects global mean sea-level rise to be between 0.44 m (0.32–0.62 m, likely range; SSP1-2.6) and 0.77 m (0.63–1.01 m, likely range; SSP5-8.5) by 2100 (medium confidence), relative to 1995–2014 (Fox-Kemper et al., 2021). Relative sea-level rise will differ regionally due to factors such as local oceanic currents or land uplift/subsidence.

Sea-level rise is expected to increase the frequency of extreme sea-level events. In many regions, a current 1-in-100-year inundation event could occur annually by 2050 (Oppenheimer et al., 2019). Flood frequency may increase exponentially, potentially doubling every five years (Taherkhani et al., 2020).

It is virtually certain that global sea level will continue rising after 2100, potentially by nearly 2 m to 7 m by 2300 (relative to 1900) under SSP5-8.5 (IPCC, 2021).

Significant uncertainties remain regarding the contributions of melting ice sheets in Greenland and Antarctica. Recent data suggest accelerating melt, raising concerns about potential tipping points (King et al., 2020; Ripple et al., 2023).

Metrics and numeric limits

Oppenheimer et al. (2019) state that in the context of sea-level rise and low-lying islands/coasts, 'sea level' refers to the time-averaged height of the sea surface, excluding short-term fluctuations such as tides and waves. They add:

- *Global mean sea-level (GMSL)* rise results from warming (lower water density) and added water mass from land ice or terrestrial water loss. Volume and mass changes redistribute ocean water, deform the lithosphere, and shift Earth's gravity field, creating regionally distinct sea-level patterns.
- Other processes–tectonics, mantle dynamics and glacial isostatic adjustment–also alter sea level through vertical land motion (VLM).
- Thus, relative sea-level (RSL) change refers to the change in the elevation difference between land and sea surface at a specific location (Farrell and Clark, 1976). Regional sea level refers to spatial scales of approximately 100 km, while local sea level refers to scales smaller than 10 km. In most locations globally, current annual mean rates of RSL change are typically on the order of a few mm yr^{-1}.
- Risk associated with changing sea level is also related to individual events of limited duration, superimposed on the background of gradual changes. As a result, these long-term temporal and spatial changes must be assessed alongside processes that lead to flooding and erosion events. Such processes include storm surges, waves and tides, or a combination thereof, and can result in extreme sea-level (ESL) events.
- Newly emerging understanding of these episodic and gradual aspects of sea-level change is assessed within the context of observed changes over the past century, as well as those inferred from longer geological timescales. This longer-term perspective is important for contextualising future sea-level projections and for improving process-based models of individual sea-level rise (SLR) components, particularly ice sheets. In addition, anthropogenic subsidence may significantly affect local sea levels in many areas, but this process is not included in the projected SLR values reported here unless specifically stated (Oppenheimer et al., 2019).

Key relevant UN convention/multilateral treaty

UN Climate Change Paris Agreement (2015) The Paris Agreement builds on the United Nations Framework Convention on Climate Change (UNFCCC) (UN and UNFCCC, 2011) and, for the first time, brings all nations into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects, with enhanced support to assist developing countries to do so. As such, it charted a new course in the global climate effort. By February 2023, 195 out of 198 Parties had ratified the Paris Agreement (United Nations Climate Change, 2015; United Nations Treaty Collection, 2024).

UN Convention on the Law of the Sea (UNCLOS) lays down a comprehensive regime of law and order in the world's oceans and seas, establishing rules governing all uses of the oceans and their resources. It enshrines the notion that all problems of ocean space are closely interrelated and must be addressed as a whole. UNCLOS entered into force in accordance with its Article 308 on 16 November 1994 (UNCLOS, 2018).

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Sea-level rise is driven by various factors acting on different timescales. For example, storms and tsunamis generate sea-level rise at the coast over short timescales, while global warming and glacial isostatic adjustment (the vertical movement of continents in response to changes in overlying ice mass) drive sea-level rise over longer periods.

Human activities such as groundwater extraction and urbanisation can lead to aquifer depletion, soil compaction and land subsidence (Hasan et al., 2023), further amplifying sea-level rise. Additionally, the loss of coastal ecosystems due to anthropogenic pressures (e.g. coral reefs and mangroves, which act as natural buffers against sea-level rise) can further intensify the impacts of sea-level rise in coastal areas.

Impacts: Sea-level rise causes a range of impacts in coastal areas, including changes in coastline morphology (erosion and accretion), coastal inundation and the degradation of coastal vegetation.

Sea-level rise modifies sediment transport along coasts through changing water currents, sediment sources and deposition zones. As a result, erosion and accretion may occur in different places and at varying rates. Although erosion is expected to be widespread and poses an existential threat to atoll islands, research suggests that some atolls are responding to sea-level rise by reshaping rather than shrinking (e.g. McLean and Kench, 2015; Duvat, 2019). While this may not reduce total land area, it does affect infrastructure and livelihoods in erosion-prone zones (see GH0405 on coastal erosion).

Sea-level rise also causes coastal inundation through overwash (Ford et al., 2018), resulting in damaged infrastructure, salinisation of groundwater and soil, and reduced crop yields. Many atoll islands already face water stress due to limited freshwater availability.

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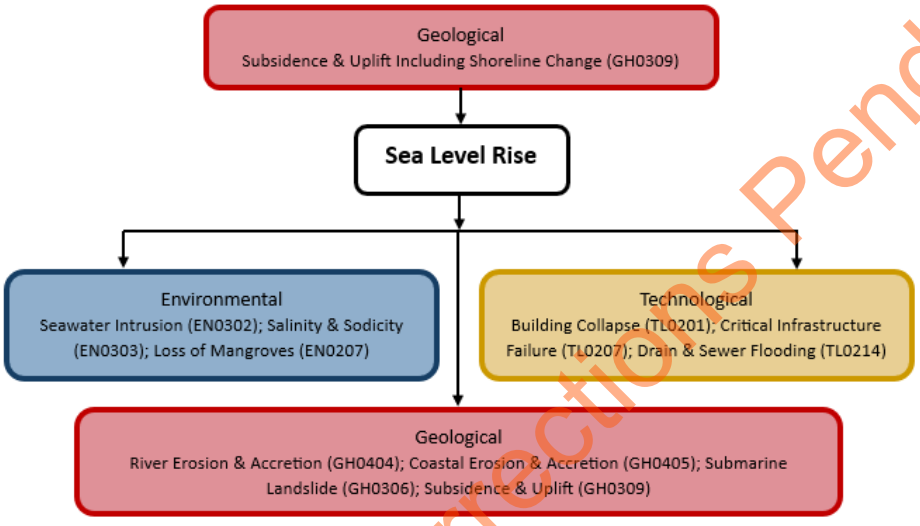
Increased frequency of overwash-related inundation could make some islands uninhabitable by depleting their freshwater supplies (Storlazzi et al., 2018).

Sea-level rise in atoll islands may also cause inundation by elevating the fresh underground water lens (e.g. Habel et al., 2019). Although this type of inundation involves freshwater, which is less corrosive to infrastructure and less harmful to soil and crops, it is more difficult to manage, as conventional coastal protection strategies are ineffective against it.

Coastal vegetation is distributed according to salt tolerance. Rising sea levels will push vegetation inland, but where there is no room for retreat, ecosystems may be reduced or lost entirely (Oppenheimer et al., 2019).

Multi-hazard Context: The figure below summarises common interactions between sea-level rise and other hazards. This information should be used with caution and should not be solely relied upon in disaster risk management, particularly as not all interactions may be included. Hazardous events occurring concurrently or in proximity may not necessarily cause, amplify, or relate to one another. Specific examples of the multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Sea-level rise is closely linked to other hazards, creating a multi-hazard environment characterised by cascading and compound events, as well as other factors that may further amplify its impacts. For example, sea-level rise exacerbates the effects of storm surges and coastal flooding, which in turn can lead to saltwater intrusion into freshwater systems, affecting coastal food production and freshwater supplies.

Compound events, such as a tropical cyclone occurring simultaneously with high tides, can contribute to coastal flooding (Tu'uholoaki et al., 2023). Conversely, such hazards can degrade built coastal defences (e.g. seawalls) and protective ecosystems (e.g. mangroves), making them more vulnerable to future sea-level rise, tropical cyclones and tides. Cascading hazards arise when sea-level rise or prolonged coastal flooding disrupts infrastructure, triggering economic, health and environmental impacts. These disruptions can also lead to conflicts over resources (e.g. fisheries) and cause population displacement.

Monitoring: The section and the table below provide an overview of monitoring for sea-level rise. This information may be used for forecasting within a national early warning system (EWS). As EWS capacities and processes vary between countries, the most current and specific information should be obtained from the appropriate national or regional agency or authority responsible for disaster management.

Which institution(s) produce(s) disaster risk data/information?	Data integration through global networks such as the Global Sea Level Observing System (GLOSS) and regional initiatives like the Pacific Islands Sea Level Monitoring Project facilitates comprehensive monitoring efforts.
How is the hazard observed/monitored/forecast?	Advanced monitoring technologies—such as satellites, tide gauges and ocean sensors—collect real-time data on sea-level trends and contributing factors, including ocean temperature and ice melt.

Risk Management: Risk management for sea-level rise may be achieved through the reduction of greenhouse gas emissions. However, there is a lag of several decades between emissions reductions and a decline in sea-level rise, since the processes involved (thermal expansion due to ocean warming and ice sheet melting) respond to atmospheric warming with delay (Oppenheimer et al., 2019).

Risk management strategies for the impacts of sea-level rise at the coast are similar to those used for coastal erosion (see GH0405). These include the design and construction of engineering structures (e.g. seawalls, revetments), conservation and restoration of healthy coastal ecosystems (e.g. coral reefs and mangrove forests), development of legislation and policies on coastal zoning and building codes, and integrated coastal management with monitoring of extreme sea-level rise events (Spalding et al., 2014).

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Existing frameworks–such as NOAA's Sea Level Rise Viewer and the Netherlands Delta Programme–demonstrate how early warning systems (EWS) can combine long-term planning with immediate risk mitigation. However, significant gaps remain, particularly in underserved regions.

Risk management related to sea-level rise, especially in connection with storm surges, waves and tides–or combinations of these contributing to extreme sea-level (ESL) events–also includes the development of effective climate information and EWS. These systems enhance preparedness by delivering timely alerts and actionable information to minimise human and economic losses.

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Coordinating agency or organisation

Not identified.

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EN0403 / ENVIRONMENTAL / Environmental Degradation

Eutrophication

Definition

Eutrophication refers to the phenomenon of increased production of organic matter, primarily nitrogen and phosphorus, in aquatic systems (Nixon, 1995). Eutrophication can be caused by human activities (e.g. sewage outfall, agricultural runoff, aquaculture) and may result in secondary environmental effects such as algal blooms and fish kills (NOAA, 2007; UNEP, 2015). Given the complex structure and functioning of ecosystems, and the multitude of pressures they face (Cloern, 2001), the precise definition of eutrophication remains to be established (Pannard et al., 2024).

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Annotations

Synonyms

Nutrient pollution

Additional scientific description

Eutrophication results from the overabundance of nutrients, primarily nitrogen and phosphorus, introduced into aquatic environments from sources such as sewage outfalls and agricultural runoff (Akinnawo, 2023). This nutrient loading accelerates the growth of algae and other aquatic vegetation. The subsequent degradation of organic matter depletes dissolved oxygen, leading to oxygen deficiency. This hypoxia has multiple cascading effects on the ecosystem, including the death of aquatic species, toxin production, and changes in aquatic community structure (Chrislock et al., 2013).

Where there are narrow continental shelves, certain wind conditions can bring nutrient-rich, oxygen-poor water into coastal zones, producing hypoxic (low-oxygen) or even anoxic (no-oxygen) conditions in which eutrophication can develop (Altieri, 2019). Such conditions have been observed on the western coasts of the American continent immediately north and south of the equator, the western coast of sub-Saharan Africa, and the western coast of the Indian subcontinent (United Nations, 2021). Dead zones and low-

oxygen areas caused by eutrophication and climate change can have severe environmental, economic, and social consequences (United Nations, 2021).

Metrics and numeric limits

There is currently no single, universal set of numeric limits for eutrophication. However, a combination of metrics, together with an understanding of local ecosystem characteristics, can facilitate the assessment of eutrophication risk and inform appropriate management strategies. Key indicators include:

- Chlorophyll-a concentration (μg L^{-1}): used as a proxy for phytoplankton biomass.
- Dissolved oxygen percentage saturation: used to determine whether water is supersaturated or undersaturated in oxygen; as oxygen solubility depends on temperature and salinity, these parameters should also be measured.
- Nutrient concentrations (μM dm^{-3}) and nutrient (atomic) ratios: deviations from the 'Redfield' nitrogen-to-phosphorus (N:P) ratio and shortages of silicate relative to nitrogen and phosphorus can provide critical insights.

Key relevant UN convention/multilateral treaty

The UNECE Convention on Long-range Transboundary Air Pollution adopted the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone in Gothenburg, Sweden, on 30 November 1999. The Protocol sets national emission ceilings from 2010 to 2020 for four pollutants: sulphur (SO_2), nitrogen oxides (NO_x), volatile organic compounds (VOCs), and ammonia (NH_3).

Sustainable Development Goal (SDG) Target 6.3 (water quality) and SDG Target 14.1 (marine pollution) directly address nutrient pollution from land-based sources, aligning eutrophication with the broader global sustainability agenda. (https://sdgs.un.org/2030agenda). Although these are not binding, they provide useful guidance.

Examples of hazard drivers, impacts and risk management

Hazard Drivers: While there are some causes of natural eutrophication (Knight, 2021), the primary drivers stem from human activity. Untreated or inadequately treated sewage remains a major source of nitrogen and phosphorus, often originating from municipal wastewater or agricultural runoff containing human waste (Akinnawo, 2023). Biomass processing industries such as food processing, animal feed production, and pulp and paper mills also contribute organic matter and nutrient-rich wastewater when not properly managed (Tusseau-Vuillemin, 2001).

Intensive agricultural practices, particularly overuse of fertilisers and manure, as well as soil erosion due to cultivation techniques, contribute to nutrient runoff into water bodies (Akinnawo, 2023). Aquaculture can also contribute to eutrophication through nutrient-rich feed and fish waste (Talbot, 1994). Atmospheric deposition of nitrogen oxides (NO_x) from fossil fuel combustion may increase nutrient enrichment in water bodies via precipitation (Paerl, 1995).

Land-use changes–including urbanisation, deforestation, drainage of wetlands, removal of riparian vegetation, and damming of rivers–disrupt natural nutrient cycling and filtration, increasing nutrient loads in aquatic systems (Rodríguez-Gallego et al., 2017).

Environmental stressors such as rising sea surface temperatures and increased salinity can intensify stratification, limiting vertical mixing and promoting algal growth (Coffey et al., 2018). Flooding can flush fertilisers and sewage into water bodies, increasing nutrient loads (Nazari-Sharabian et al., 2018). Forest fires also contribute to eutrophication by releasing nitrogen oxides into the atmosphere, which are later deposited over water bodies (Paerl, 1995).

Impacts: Eutrophication causes cascading effects on aquatic ecosystems. Nutrient enrichment favours fast-growing phytoplankton, leading to shifts in phytoplankton community structure (Chrislock et al., 2013). Reduced light penetration and algal overgrowth result in the loss of seagrass habitats essential for marine biodiversity (Pick, 1991). Oxygen depletion from decaying biomass leads to hypoxic or anoxic conditions, causing fish kills and harming benthic organisms (Akinnawo, 2023).

These changes disrupt food webs, reduce biodiversity, and compromise the overall health and resilience of aquatic ecosystems (Chrislock et al., 2013).

Eutrophication acts as a trigger point for a series of secondary hazards, further exacerbating the problem. As organic matter from algal blooms decomposes under anoxic conditions, it releases toxic gases such as hydrogen sulfide, which can affect aquatic life and pose a serious threat to human health (Dunnette et al., 1985). Additionally, eutrophication creates ideal conditions for the accumulation of persistent organic pollutants (POPs) and heavy metals. These pollutants, originating from various sources including industrial waste, bind to organic particles in the water and become incorporated into the food web. As they move up the food chain through a process known as biomagnification, their concentrations increase, posing long-term ecological and human health risks (Larsson et al., 2000).

The consequences of eutrophication extend beyond ecological damage. Certain algal blooms can produce toxins such as microcystins and saxitoxins that pose a public health risk to humans (Gody et al., 2019; Brooks et al., 2016). These toxins can also sicken or kill animals within the aquatic ecosystem and threaten human health through contaminated drinking water or seafood

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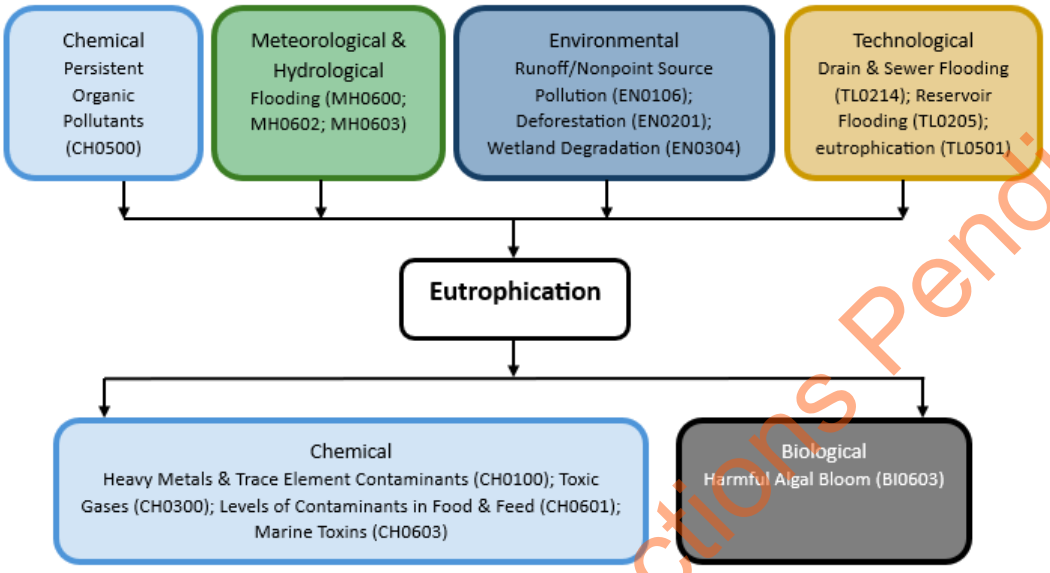
consumption (Brooks et al., 2016). Additionally, fish kills and decreased fishery productivity can lead to economic losses for commercial and recreational fisheries (Kerr et al., 1992). Finally, eutrophication can render water bodies unsuitable for recreational activities such as swimming and boating due to the unpleasant aesthetics associated with algal blooms (Priskin, 2008).

Multi-hazard Context: The figure below summarises common interactions between eutrophication and other hazards. This information should be used with caution and not be solely relied upon in disaster risk management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of the multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring for eutrophication. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) disaster risk data/information?	Environmental agencies.
How is the hazard monitored/observed/forecast?	Monitoring the concentrations of nitrogen and phosphorus in water bodies is a critical early warning tool for eutrophication, despite the lack of universally standardised thresholds across different regions. Thresholds can vary depending on factors such as water depth, flow, and natural background levels. Significant and sustained increases in nutrient levels can serve as a red flag, prompting further investigation (Yang et al., 2008). A decline in water clarity suggests an increase in suspended algae and organic matter, a hallmark of eutrophication (Pick, 1991). Technological advancements can facilitate this assessment; for example, ocean colour remote sensing allows for the monitoring of algal blooms over vast areas, providing a large-scale perspective on potential eutrophication risks (Banks et al., 2012). A sudden drop in dissolved oxygen levels at night can serve as a critical early warning. This 'night-time oxygen sag' indicates an intensified imbalance between oxygen production and consumption, potentially leading to hypoxic or anoxic events where aquatic life struggles to survive. This imbalance can be further exacerbated by the decomposition of organic matter from algal blooms (Miranda et al., 2001). Biodiversity loss is another crucial early warning sign. Eutrophication can favour certain species, particularly nuisance or invasive algae, while displacing others that are more sensitive to nutrient enrichment (Rosset et al., 2014). In some cases, ecosystems may exhibit multiple critical mutation points, indicating that degradation and collapse due to eutrophication can occur rapidly (Wang et al., 2012).

Risk Management: Risk management combines source control (e.g. wastewater treatment), in-system measures (e.g. biomanipulation), and policy (e.g. effluent standards). Context-specific approaches are essential (UNESCO, 2015).

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Coordinating agency or organization

UNEP Global Partnership on Nutrient Management

Preliminary – Corrections Pending

EN0404 / ENVIRONMENTAL / Environmental Degradation

Coral Bleaching

Definition

Corals are subject to 'bleaching' when the seawater temperature is too high: they lose the symbiotic algae that give coral its colour and part of its nutrients. Severe, prolonged or repeated bleaching can lead to the death of coral colonies (United Nations, 2017).

Reference

Reference United Nations, 2017. The First Global Integrated Marine Assessment: World Ocean Assessment I. Cambridge University Press. www.un.org/Depts/los/global_reporting/WOA_RPROC/WOACompilation.pdf (Accessed 25 February 2025).

Preliminary – Corrections Pending

Annotations

Synonyms

Not identified.

Additional scientific description

Additional scientific description

Corals are symbiotic organisms with the coral polyp hosting photosynthetic zooxanthellae algae for mutual benefit. In times of stress, the polyp expels the algae, affecting coral growth and reproduction and leading to bleaching. When bleaching persists, it can result in coral starvation and death (Saxena et al., 2023).

Coral bleaching is a relatively modern phenomenon. Prior to 1980, it was rarely observed and considered a local issue. Since then, both the frequency and severity of bleaching events have increased. The percentage of corals damaged globally due to bleaching rose from 8% per annum in the 1980s to around 31% in 2016 (Saxena et al., 2023).

An increase of only 1°C to 2°C above the seasonal maximum can induce bleaching. While most coral species are susceptible to bleaching, thermal tolerance varies. Many heat-stressed or bleached corals subsequently die from coral diseases (United Nations, 2017; 2021).

Increasingly frequent severe coral bleaching is one of the greatest threats to coral reefs from climate change. Global climate models project wide spatial variation in the timing of annual severe bleaching events–a point beyond which reef recovery becomes limited (UNEP, 2017).

In 2005, the USA lost half its coral reefs in the Caribbean due to a major bleaching event. Warm waters centred around the northern Antilles extended southward. Satellite data showed that thermal stress from this event exceeded the previous 20 years combined (NOAA, no date a).

In 2020, bleaching was reported around Hainan Island and the Beibu Gulf. The Great Barrier Reef experienced mass bleaching in 1998, 2002, 2006, 2016, 2017, and 2020. The Global Coral-Bleaching Database (GCBD) includes 34,846 bleaching records from 14,405 sites in 93 countries (Saxena et al., 2023).

Annual severe bleaching onset is defined as more than eight degree-heating weeks (DHWs) within a three-month period. At this threshold, thermal stress is likely sufficient to cause bleaching (van Hooidonk et al., 2016)

Metrics and numeric limits

The NOAA Coral Reef Watch daily global 5 km satellite coral bleaching Degree Heating Week (DHW) product measures accumulated

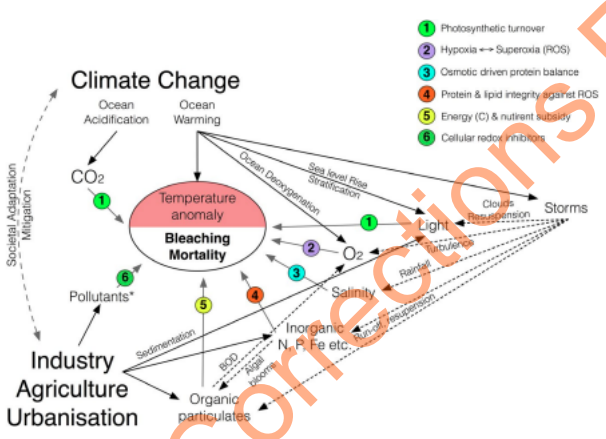
heat stress that can lead to coral bleaching and mortality. A DHW value of 4 °C-weeks indicates a risk of bleaching. At 8 °C-weeks, reef-wide bleaching with mortality among heat-sensitive corals is likely. If the DHW reaches 12 °C-weeks, multi-species mortality becomes likely. When values reach 16 °C-weeks, severe mortality affecting more than 50% of corals is expected, and at 20 °C-weeks or above, near-total mortality (in excess of 80%) is probable (NOAA, 2018).

Key relevant UN convention/multilateral treaty

The Convention on Biological Diversity (1992) includes objectives to conserve biodiversity, sustainably use its components, and fairly share the benefits from genetic resources.

Examples of hazard drivers, impacts, and control measures of the hazard

Hazard Drivers: The main drivers for coral bleaching are climate change and heat. Multiple reef stressors, such as erosion, solar radiation, rising sea surface temperatures, pollution, sedimentation due to deforestation and construction, predation, variable salinity, infections, disease outbreaks, and increased virulence, as well as overfishing and destructive fishing practices, have been associated with the loss of symbiotic algae in corals. Bleaching can be induced by subjecting corals to suboptimal conditions of any factor central to growth and survivorship. Bleaching occurs where severe ("lethal") doses of any one environmental factor occur, and also when moderate ("sublethal") doses operate in combination. The complexity of the drivers affecting coral bleaching is summarised in the figure below (Suggett and Smith, 2019).



Climate change is considered the major cause of coral bleaching. Evidence strongly supports the role of marine heatwaves as the primary driver of mass bleaching events. Heatwave severity is measured as Degree Heating Weeks (DHWs), reflecting the cumulative time during which sea surface temperatures (SSTs) exceed the seasonal norm. All environmental factors mentioned above influence the timing and severity of heat stress-induced bleaching. This complex interaction has led researchers to describe the system as one where "all roads can lead to [some form of] coral bleaching" (Suggett and Smith, 2019). Because coral polyps tolerate only a narrow thermal range, a rise of just 1-2°C can initiate mass bleaching. While bleaching is reduced in shaded reef systems, it is more pronounced in areas exposed to elevated light conditions (Saxena et al., 2023).

High turbidity caused by silt and contaminants reduces light availability to coral reefs, increasing their vulnerability. Additional hazards such as frequent and intense tropical cyclones, ocean acidification, and ozone depletion (which increases UV radiation) further stress corals and increase bleaching risk. Eutrophication of coastal waters is also contributing to increased coral mortality (Lesser, 2021).

Impacts: Coral reef degradation caused by bleaching significantly affects fisheries, as corals provide nutrition and habitat for numerous fish species and reef-associated marine fauna. The decline in reef fish populations has reduced the numbers of larger predatory species. These impacts severely affect coastal communities in the tropics that rely on coral reef-based fisheries for livelihood, income, and food security. There is also a cascading effect on industrialised nations that import seafood from reef ecosystems (Saxena et al., 2023).

Coral reefs act as natural wave barriers. The loss of reef integrity due to mass bleaching has made coastlines more vulnerable to damage in the past decade (Saxena et al., 2023).

Economic assessments estimate global losses in coral reef value under climate change to range from US$3.4 billion to US$23.78 billion annually (Chen et al., 2015; coast.noaa.gov/states/fast-facts/coral-reefs.html).

Multi-hazard Context: The figure below summarises common interactions between coral bleaching and other hazards. This information should be used with caution and not be solely relied upon in disaster risk management, particularly as some interactions may not have been included. Note that hazardous events occurring together or in proximity in space or time may not necessarily cause, amplify, or be otherwise related to one another. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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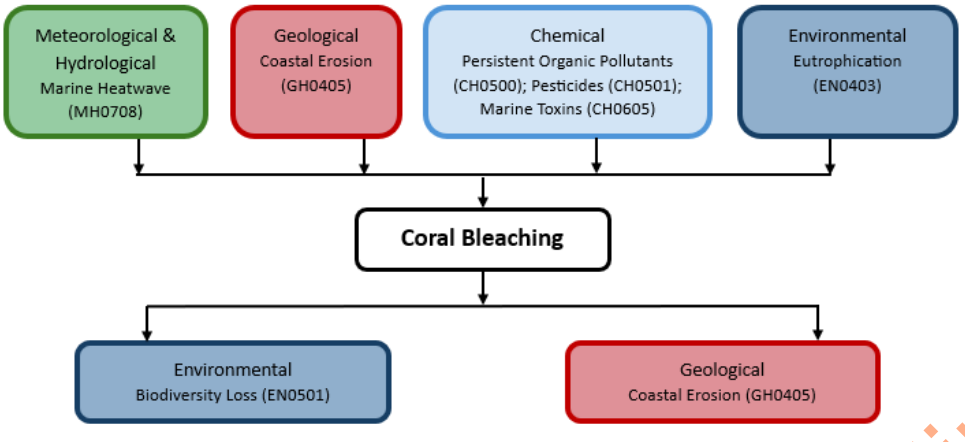

Monitoring: The section above and the table below provide an overview of monitoring for coral bleaching. This information may support forecasting within a national early warning system (EWS). As EWS capacities and processes vary across countries, the most current and specific information should be obtained from the relevant national or regional agency or authority responsible for disaster management.

Which institution(s) produce(s) disaster risk data/information?	NOAA Coastal Communities
How is the hazard monitored/observed/forecast?	The National Oceanic and Atmospheric Administration (NOAA) Coral Reef Watch programme uses satellite data to provide current reef environmental conditions and to rapidly identify areas at risk of coral bleaching (NOAA, no date b). Coral Reef Watch also offers a modelled outlook that predicts the likelihood of coral bleaching heat stress on a week-by-week basis, up to four months in advance (the typical duration of a bleaching season). Continuous satellite monitoring of sea surface temperatures at global scales, along with modelled projections of approaching bleaching-level heat stress, provides resource managers, scientific researchers, and other coral reef ecosystem stakeholders with tools to understand and better manage the complex interactions that lead to coral bleaching. When bleaching conditions arise, these tools can be used to trigger bleaching response plans and to support appropriate management decisions and public communication (NOAA, no date b). In addition, citizen science has been used to monitor the extent of a coral bleaching event in the Philippines in 2020, highlighting the role of local communities in measuring the impact of disturbances such as coral bleaching—particularly when appropriate methods, tools, and governmental support are available (Licuanan and Mordeno, 2021).

A Global Coral-Bleaching Database (GCBD), encompassing 34,846 coral bleaching records from 14,405 sites across 93 countries between 1980 and 2020 (Global Coral Bleaching Database (NCEI Accession 0228498). The GCBD provides vital information on the presence or absence of coral bleaching, along with site exposure, distance to land, mean turbidity, cyclone frequency, and a suite of sea surface temperature metrics recorded at the time of survey (van Woesik and Kratochwill, 2022). This database has supported various models aimed at identifying contributing factors to coral bleaching (Zheng, 2024).

Risk Management: The recurrence of mass coral bleaching events in recent years has highlighted the need to protect coral reefs and support their adaptation to climate change. Multiple approaches are possible.

One approach focuses on protecting the environmental conditions in which corals grow to improve their health and reduce the impacts of heatwaves. Established practices include the use of marine protected areas (MPAs), which reduce fishing pressure on coral reefs, enhance opportunities for coral larvae recruitment, and provide some buffering against extreme events. Effective regulation of land-derived nutrient inflows that promote algal growth and exacerbate coral sensitivity to heat-induced bleaching is also a necessary step (Suggett and Smith, 2019).

Another approach aims to enhance the adaptive capacity of corals to withstand higher temperatures. Corals have shown the ability to develop resistance (defying bleaching), tolerance (surviving in a bleached state), and recovery (returning to a healthy state post-bleaching). These capacities vary across individuals and species. Some show visible signs of bleaching only after 1-2 weeks at 1.5°C above normal, while others in the same location may remain unbleached for more than 4-6 weeks (Saxena et al., 2023). Understanding these dynamics can help inform targeted interventions.

Coral restoration projects are under way in many countries. Some initiatives involve coral farming or propagation, in which large corals are broken into small fragments or miniature polyps (ranging from 1 to 5 in number). These fragments trigger the formation of clones that grow to 25-50 times the size of the original coral. These cloned fragments then recognise and fuse with one another to form large colonies. Once matured–after approximately 4-12 months–they are returned to the ocean or a designated

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restoration site (Saxena et al., 2023). Other methods involve placing underwater structures that encourage coral larvae settlement and growth. In 2020, a novel restoration project in the Gulf of Kachchh, Gujarat, India, used an electric current passed through Bio-rock (mineral accretion). This process facilitates the bonding of calcium and carbonate ions to form calcium carbonate, on which coral larvae settle and grow rapidly without expending their own energy (Saxena et al., 2023).

However, these restoration and adaptation strategies alone are currently insufficient to counteract the broader effects of climate change. For long-term effectiveness and to prevent catastrophic, large-scale coral loss, they must be combined with reductions in greenhouse gas emissions (Suggett and Smith, 2019).

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Coordinating agency or organisation

Not identified.

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EN0405 / ENVIRONMENTAL / Environmental Degradation

Sand Mining

Definition

Sand mining (extraction) is defined as the removal of primary (virgin) natural sand and sand resources (mineral sands and aggregates) from the natural environment (terrestrial, riverine, coastal, or marine) for extracting valuable minerals, metals, crushed stone, sand and gravel for subsequent processing (UNEP, 2019).

Reference

UNEP, 2019. Sand and Sustainability: Finding new solutions for environmental governance of global sand resources. GRID-Geneva, United Nations Environment Programme (UNEP). https://wedocs.unep.org/bitstream/handle/20.500.11822/28163/SandSust.pdf Accessed 21 January 2025.

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Annotations

Synonyms

Sand extraction.

Additional scientific description

The United Nations Environment Programme report on Sand and Sustainability (UNEP, 2019) describes the following materials as being extracted or mined from the natural environment:

- Natural sands: all sands extracted from natural environments.
- Mineral sands: part of a class of ore deposits that contain heavy metals such as ilmenite, zircon, leucoxene, and rutile. Eroded materials from hard rock sources like granite or basalt accumulate on beaches, within river systems, and on coastlines. These materials are extracted for end-use in jewellery, as pigments in paints, plastics, paper, and foods, and in electronics.
- Aggregates: crushed rock, sand, and gravel used in construction, minerals and water filtration.
  - Primary aggregates consist of crushed rock extracted in hard rock quarries by blasting and crushing, and sand and gravel extracted from pits by excavation and crushing, from lakes, rivers, coastal beaches, or dredged from the sea.
  - Recycled aggregates: crushed rock, sand, and gravel produced by sorting, crushing, and screening of construction and demolition materials.
  - Manufactured aggregates: substitutes for crushed rock, sand, and gravel that are produced from waste from other industries.

The environmental and social impacts of sand extraction are issues of global significance. Eroded materials from hard rock sources, sands, and gravels are the unrecognised foundational materials of national economies. They are mined globally, with aggregates accounting for the largest volume of solid material extracted worldwide (UNEP, 2014; 2019).

Metrics and numeric limits

There is a lack of adequate information on sand mining, limiting the regulation of extraction in many low- and middle-income countries (Sreebha and Padmalal, 2011). Access to data is difficult, and data are not standardised. This absence of global data makes environmental assessment very difficult (UNEP, 2014).

An estimated 40 to 50 billion metric tonnes of crushed rock, sand, and gravel are extracted every year (Steinberger et al., 2010; UNEP, 2014; 2019).

One way to estimate the global use of aggregates indirectly is through the production of cement for concrete (concrete is made with cement, water, sand, and gravel) (UNEP, 2014; 2019).

Key relevant UN conventions or multilateral treaties

Not identified.

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Lack of monitoring systems, regulatory policies, and environmental impact assessments have led to indiscriminate mining, triggering severe damage to the environment and related ecosystem services (UNEP, 2014). The absence of global monitoring of aggregate extraction contributes to a knowledge gap that translates into a lack of action. As this is a major emerging issue, there is a need for in-depth research (UNEP, 2014).

Impacts: Sand mining may lead to environmental degradation, including:

- *Loss of biodiversity:* via pollution and direct impacts on the biophysical integrity of ecosystems (UNEP, 2014). Removing significant amounts of material from dynamic environments such as rivers and coasts, or static environments such as quarries, results in widespread environmental change. Marine sand mining via benthic dredging causes changes in water turbidity and leads to a net decline in faunal biomass and abundance (Desprez et al., 2010), or a shift in species composition (UNEP, 2014).
- *Land losses:* inland through aggregate extraction and river erosion, and coastal through extraction and erosion. Agricultural production can be affected by the loss of agricultural land from river erosion (UNEP, 2014).
- *Hydrological function:* changes in water flows, flood regulation, and marine currents. Removing sediment from rivers causes the river to cut its channel through the bed of the valley floor upstream and downstream of the extraction site. This leads to coarsening of bed material and lateral channel instability (UNEP, 2014).
- *Water supply: m*ainly through lowering of the water table and pollution. Marine aggregates need to be thoroughly washed to remove salt. For example, the removal of over 12 million tonnes of sand per year from the Vembanad Lake catchment in India has led to the lowering of the riverbed by 7-15 cm/year (Padmalal et al., 2008). Sand mining can lead to a loss of aquifer storage (Kondolf, 1997). The lowering of the water table can affect agricultural production.
- *Climate:* direct emissions from transport and indirect emissions from cement production (UNEP, 2014).

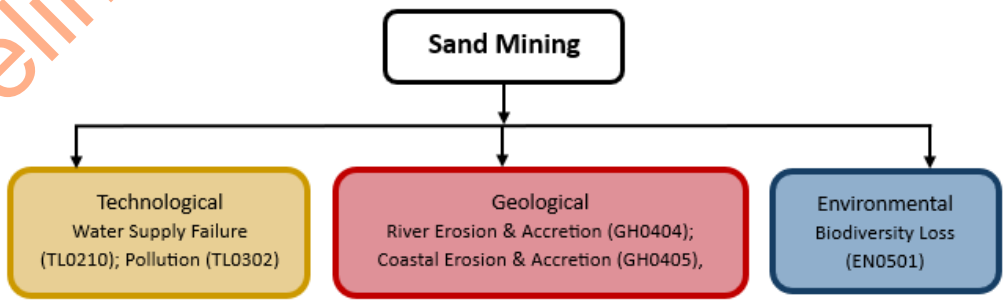
Landscape: coastal erosion, changes in deltaic structures, quarries, and river pollution. Erosion occurs from direct sand removal from beaches, near-shore marine dredging, or river sand mining (Tripathi et al., 2025). Damming and mining have reduced sediment delivery from rivers to many coastal areas, accelerating beach erosion. Many sand extraction operations in low- and middle-income countries are not in line with relevant environmental regulations. Often, mining and dredging regulations are introduced without a scientific understanding of their consequences. For instance, in-stream mining might be environmentally sustainable if restricted to the value of the annual bed load.

Illegal activities, such as those conducted by 'sand mafias', are widespread (UNEP, 2014; 2019). Most sand from deserts cannot be used for concrete or land reclamation, as wind erosion forms round grains that do not bind well (Zhang et al., 2006).

Direct safety risks: include industrial accidents (e.g. drowning of workers removing sand from riverbeds), health effects from dust and hydrocarbon pollution, forced child labour, transport accidents, subsidence, and landslides (Maya et al., 2012; UNEP, 2014; 2019).

Sand mining may reduce protection against extreme events such as floods, droughts, and storm surges (UNEP, 2014).

Multi-hazard Context: The figure below summarises common interactions between sand mining and other hazards. This information should be used with caution and not be solely relied upon in disaster risk management, particularly as some interactions may not be included. Specific examples are provided in the 'Hazard drivers' and 'Impacts' sections.



Monitoring: No Information Available

Risk Management: Training of architects and engineers, new laws and regulations, taxation, and positive incentives are needed to reduce dependency on sand. The use of renewable and recycled materials in construction should be prioritised (UNEP, 2014; 2019).

There is a need to regulate sand extraction in both national and international waters (UNEP, 2014; 2019).

Preliminary – Corrections Pending

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Coordinating agency or organisation

Not identified.

Preliminary – Corrections Pending

EN0501 / ENVIRONMENTAL / Environmental Degradation

Biodiversity Loss

Definition

Biodiversity loss refers to the reduction of any aspect of biological diversity (i.e. diversity at the genetic, species and ecosystem levels) in a particular area through death (including extinction), destruction or manual removal. It can occur at many scales, from global extinctions to local population extinctions, leading to a decline in total diversity at the same scale.

Preliminary – Corrections Pending

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Annotations

Synonyms

None identified.

Additional scientific description

Additional scientific description

Biodiversity loss refers to the reduction in the variety and abundance of life on Earth, encompassing genetic, species and ecosystem levels. This decline reflects a reduction in nature's functional capacity to deliver ecosystem services, such as pollination, climate regulation, water purification and nutrient cycling. It highlights the ecological interdependence of species and the need to maintain biodiversity for human wellbeing.

Currently, more species face global extinction than ever before. Approximately 25% of assessed species groups are threatened, with up to 1 million species at risk of extinction within decades unless pressures are reduced. Extinction rates are tens to hundreds of times higher than natural background rates (IPBES, 2019).

Metrics and numeric limits

No single global metric exists for biodiversity loss. However, conservation success is measured through:

- Protected area coverage
- Achievement of biodiversity or abiotic thresholds (Bocchi, 2024; Gillson, 2015; Kapos et al., 2009)

Key relevant UN conventions / multilateral treaties

The Convention on Biological Diversity (1992) has three main objectives: the conservation of biological diversity, the sustainable use of the components of biological diversity, and the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources.

The Kunming-Montreal Global Biodiversity Framework (2022) supports the achievement of the Sustainable Development Goals and builds on the Convention's previous Strategic Plans, setting out an ambitious pathway to reach the global vision of a world living in harmony with nature by 2050. Among the Framework's key elements are 4 goals for 2050 and 23 targets for 2030.

The Convention on the Conservation of Migratory Species of Wild Animals, also referred to as the Bonn Convention and the Convention on Migratory Species (1979), is an environmental treaty under the aegis of the United Nations Environment Programme for the conservation and sustainable use of migratory animals and their habitats.

The Convention on Wetlands of International Importance Especially as Waterfowl Habitat (1971) provides the framework for the conservation and use of wetlands and their resources.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora, also referred to as CITES (1973), is an intergovernmental agreement which aims to ensure that international trade in specimens of wild animals and plants does not threaten their survival.

United Nations Convention to Combat Desertification (1994) links environmental concerns and development issues to sustainable land management practices. The World Heritage Convention (1972) recognises some World Heritage properties specifically for their outstanding biodiversity values, protecting many of the most important ecosystems, and areas of high biodiversity and mitigating against loss.

Examples of hazard drivers, impact and risk management

Hazard Drivers: The direct drivers of change leading to biodiversity loss include direct exploitation of organisms, through activities such as overfishing, hunting, poaching, and unsustainable harvesting of plants and animals that deplete populations faster than they can recover (Prakash et al., 2022). In addition, changes in land and sea resulting from increasing urbanisation, agriculture, logging, mining, infrastructure development, and other land use changes lead to the destruction and fragmentation of natural habitats, making it difficult for species to survive and reproduce (Hald-Mortensen, 2023).

Climate change is also a major driver of biodiversity loss, with alterations in temperature, precipitation patterns, and the frequency of extreme weather events disrupting ecosystems, forcing species to migrate, adapt or perish (IPCC, 2022; Wudu et al., 2023; Shivanna, 2022). This can also lead to an increase in invasive species as species move into new ecosystems in which they can survive. Non-native species can also be introduced by human activity and can outcompete, prey on, or bring diseases to native species, leading to declines or extinctions (Clements, 2021). Finally, pollution and contaminants such as pesticides, heavy metals, plastics, and industrial pollutants degrade natural habitats and harm or kill organisms (Singh et al., 2023).

The direct drivers result from an array of underlying causes (indirect drivers), underpinned by societal values and behaviours such as production and consumption patterns, human population dynamics and trends, trade, technological innovations, and local through global governance (IPBES, 2019).

Climate change, a primary driver of biodiversity loss, alters habitats, disrupts ecological processes, and increases the vulnerability of species to extinction. Conversely, biodiversity loss exacerbates climate change by reducing carbon sequestration and increasing greenhouse gas emissions. Extreme weather events, such as hurricanes, floods, and droughts, are becoming more frequent and severe due to climate change, further impacting biodiversity through habitat destruction and population decline (IPCC, 2022; Wudu et al., 2023; Shivanna, 2022).

Land-use change, driven by factors like agriculture, urbanisation, and infrastructure development, is a major contributor to habitat loss and fragmentation. This directly impacts biodiversity and can also increase the risk of other hazards like soil erosion, flooding, and water pollution (Hald-Mortensen, 2023).

Pollution, including air, water, and soil pollution, poses a significant threat to biodiversity. These pollutants can directly harm organisms, alter ecosystem processes, and reduce habitat quality. In turn, biodiversity loss can exacerbate pollution problems by weakening ecosystem resilience and reducing the ability of ecosystems to filter pollutants (Singh et al., 2023).

Invasive species, often facilitated by human activities and climate change, can outcompete native species, leading to biodiversity loss. Conversely, biodiversity loss can create ecological opportunities for invasive species to establish and spread (Clements, 2021).

Impacts: Biodiversity provides numerous ecosystem services that are critical to human wellbeing at present and in the future. Biodiversity loss will therefore have significant direct human health impacts if ecosystem services, such as pollination, water purification, flood control, and soil fertility, are no longer adequate to meet social needs (Walz et al., 2021). This has multiple knock-on effects, such as a decline in food security, as reductions in fish stocks, crop diversity, and other food sources threaten

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communities reliant on natural resources, particularly for Indigenous people who manage 25% of the world area and 80% of biodiversity (Garnett et al., 2018).

In parallel, it can also affect livelihoods and income, with sectors such as agriculture, forestry, and fisheries facing economic impacts due to declining resources and ecosystem services. Furthermore, biodiversity loss can lead to cultural losses, as many cultures have deep connections with local biodiversity. Its loss can erode cultural identity and traditional knowledge, which can ultimately increase local migration and, occasionally, may even lead to or exacerbate political conflict (Gavin et al., 2015).

In addition, the biophysical diversity of microorganisms, flora, and fauna provides important benefits for biological, health, and pharmacological sciences. Loss in biodiversity may limit the discovery of potential treatments for many diseases and health problems and can lead to the emergence and spread of infectious diseases, as diverse ecosystems can buffer against disease outbreaks (Williams et al., 2021) through the 'dilution effect' (Ferraguti et al., 2021).

In 2009, a group of researchers identified the nine processes that regulate the stability and resilience of the Earth system. They proposed quantitative planetary boundaries within which humanity can continue to develop and thrive for generations to come, provided that the boundaries are not crossed (Richardson et al., 2023; Steffen et al., 2015; Rockström et al., 2009). The researchers highlighted that transgressing one or more planetary boundaries may be deleterious or even catastrophic due to the risk of crossing thresholds triggering non-linear, abrupt environmental change at the continental-to-planetary scale. As of 2023, six boundaries, including biosphere integrity (biodiversity loss and extinctions), were crossed, while others were in imminent danger of being crossed (Richardson et al., 2023).

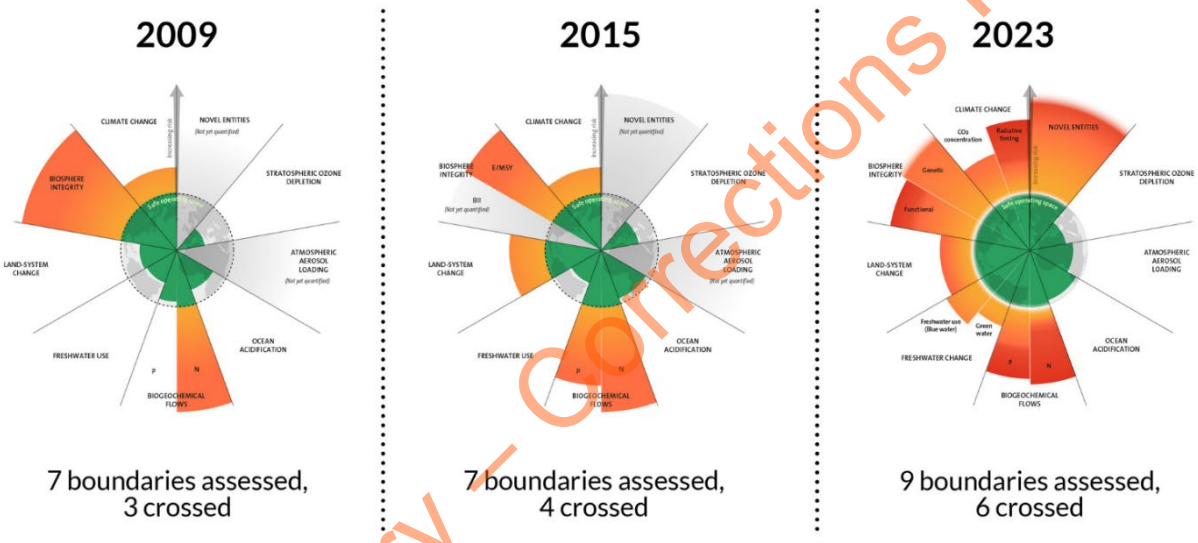

Figure 1 *The evolution of the planetary boundaries' framework. Licenced under CC BY-NC-ND 3.0 (Credit: Azote for Stockholm Resilience Centre, Stockholm University. Based on Richardson et al., 2023, Steffen et al., 2015, and Rockström et al., 2009) Biodiversity loss is intricately linked to a complex web of environmental threats. This interconnectedness amplifies the negative impacts of each hazard, creating cascading effects that threaten ecosystem resilience and human well-being. Understanding the complex interplay between biodiversity loss and other environmental hazards is crucial for developing effective conservation and management strategies.*

Multi-hazard Context: The figure below summarises common interactions between biodiversity loss and other hazards. This information should be used with caution and not be solely relied upon in disaster risk management, particularly as some interactions may not have been included. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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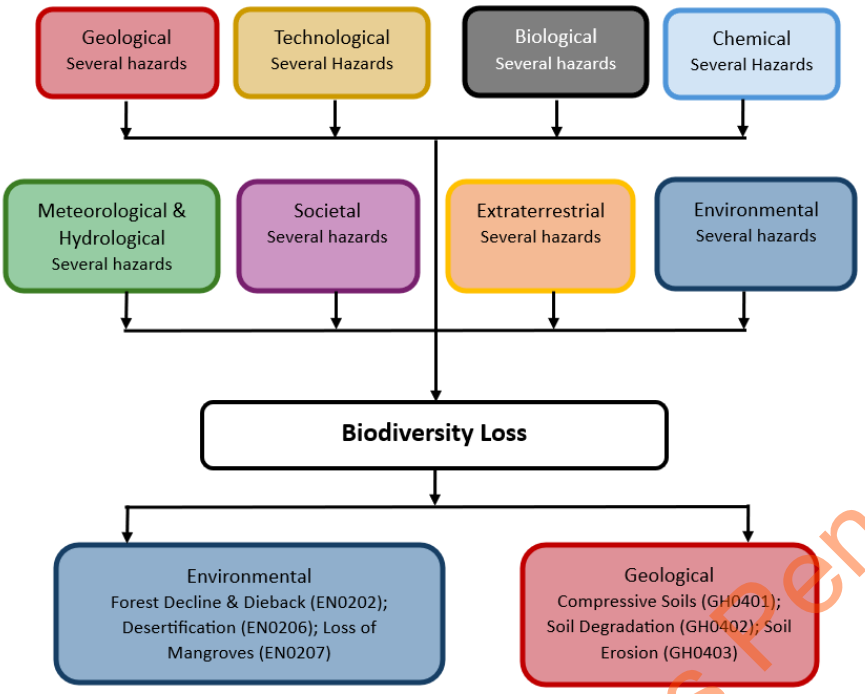

Monitoring: The section and the table below offer an overview of monitoring for biodiversity loss. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) disaster risk data/information?	Environmental agencies, biodiversity offices
How is the hazard observed/monitored/forecast?	Species population monitoring and habitat assessments remain crucial. Innovative approaches are necessary to enhance early detection capabilities. One promising avenue involves the use of biodiversity indicators. These metrics, derived from various biological, ecological, and environmental data, can provide early signals of ecosystem stress. For instance, changes in species richness, abundance, or composition can serve as indicators of biodiversity decline. Additionally, monitoring functional diversity, which assesses the range of ecological roles performed by different species, can offer insights into ecosystem resilience and vulnerability (Hobohm, 2021). Another critical component of early warning systems is the integration of genetic monitoring. Advances in molecular techniques allow for the rapid assessment of genetic diversity within populations. Declines in genetic diversity can signal population bottlenecks or inbreeding, which can increase vulnerability to environmental stressors (Banerjee, 2021). Furthermore, incorporating remote sensing technologies is essential for large-scale monitoring of biodiversity trends. Satellite imagery can provide valuable information on land cover change, habitat fragmentation, and species distribution patterns. Combining remote sensing data with ground-based observations can enhance the accuracy and effectiveness of early warning systems (Reddy, 2021).

Risk Management: The following main interventions ('levers') to generate transformative change by tackling the underlying causes of the deterioration of nature are suggested by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services: develop incentives and widespread capacity for environmental responsibility and eliminate perverse incentives; reform sectoral and segmented decision-making to promote integration across sectors and jurisdictions; take pre-emptive and precautionary actions in regulatory and management institutions and businesses to avoid, mitigate, and remedy the deterioration of nature, and monitor their outcomes; manage for resilient social and ecological systems in the face of uncertainty and complexity, to deliver decisions that are robust in a wide range of scenarios; and strengthen environmental laws and policies and their implementation, and the rule of law more generally (IPBES, 2019).

It is also important to consider integrated approaches to addressing biodiversity loss along with interventions that also address other related crises such as climate change and pollution (Schlaepfer and Lawler, 2023; Wudu et al., 2023).

Early warning systems for biodiversity loss are essential for timely intervention and effective conservation strategies.

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Coordinating agency or organization

Convention on Biological Diversity; Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

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CHEMICAL

Preliminary – Corrections Pending

CH0100 / CHEMICAL / Heavy Metals and Other Trace Elements

Heavy Metals and Other Trace Elements

Definition

Heavy metals are metallic trace elements with either high relative atomic weights or occurring in materials with high densities. Trace Elements is the term used for elements that are generally found in soil at low concentrations but can still have significant impacts on human health and ecosystems when their levels exceed safe limits, as in the case of many heavy metals. Trace element contaminants that have biological significance are generally found in soil at concentrations of less than 100 mg/kg, and sometimes in aquatic ecosystems or as particulates in the atmosphere. Biological significance would include elements that are essential or toxic to any organism; some elements can be both, depending on their concentration. Many of the trace elements of importance are metals, while others are metalloids, alloys, non-metals, actinoids, and halogens occurring in a variety of chemical states (elemental, cations, anions, oxyanions, methylated, etc.). This category can overlap or be used synonymously with terms such as potentially toxic elements, heavy metals, persistent inorganic contaminants, inorganic contaminants, and halides, such as fluoride and iodide. For the clarity of this document, the term trace elements will be used (FAO and UNEP, 2021a).

Preliminary – Corrections Pending

Reference

FAO and UNEP. 2021a. Global Assessment of Soil Pollution. Report. Rome, FAO. https://doi.org/10.4060/cb4894en Accessed 20 July 2024

Annotations

GHS classification

Synonyms

Heavy metals, Metallic elements, Metallic compounds, Alloys, Halogens, Halides, Metalloids, Metallic components, Inorganic contaminants, Potential Toxic elements, Persistent Inorganic Contaminants (PIP), Potentially Toxic Elements (PTE), Inorganic contaminants.

Additional scientific description

Trace elements can become contaminants when their concentrations significantly exceed natural levels due to anthropogenic activities, such as industrial processes, mining, agriculture, and waste disposal. These contaminants can accumulate in soil, water, and biota, potentially causing adverse effects on ecosystems and human health.

- **Essential Trace Elements**: These are elements required in small amounts for normal physiological functions. Examples include iron (Fe), zinc (Zn), copper (Cu), and selenium (Se).
- **Non-Essential or Toxic Trace Elements**: These are elements that can be toxic to organisms even at low concentrations. See other Hazard Information Profiles for examples, which include lead (Pb, CH0103), mercury (Hg, CH0104), cadmium (Cd, CH0102), and arsenic (As, CH0101).
- **Metals:** The term "metal health hazard" refers to the potential risks posed to human health by exposure to metallic substances. Metals are naturally occurring elements that are found in various forms in the environment, and while many metals are essential for life and have beneficial uses, some can be harmful when encountered in certain forms or concentrations. Health hazards associated with metals can result from exposure through inhalation, ingestion, or skin contact, depending on factors such as the specific metal involved, its chemical form, and the duration and intensity of exposure. Some common occurrences of metals: Ores, Mineral Deposits, Soil and Sediments, Water Bodies, Vegetation, Atmosphere, Manufactured Products, Waste and Recycling.
- **Metalloids:** elements that exhibit some metal and some non-metal properties.
- **Alloys:** Metals can be combined with other elements to form alloys, which often exhibit properties superior to those of the individual elements. Common alloys include brass (copper and zinc), bronze (copper and tin), stainless steel (iron, chromium, and nickel), and aluminum alloys.
- **Non-Metal Contaminants:** elements or ions that have the potential to be contaminants in soil and water. Because of their high ionic potential, non-metals of Groups 13 to 16 of the Periodic Table in their normal oxidation states form oxyanions.
- **Halides**, the anions from Group 17 such as fluoride, chloride, bromide, and iodide are considered additionally as phytotoxic air pollutants and can have a severe impact on health at high concentrations. High bromide concentrations can have lethal effects on aquatic organisms. In addition, halides are scavengers of hydroxyl radical during advanced oxidation processes, reducing efficiency of several water treatment efforts.

Unlike organic contaminants, which can be degraded when metabolized by different organisms, trace elements cannot be degraded by metabolic processes. However, an essential peculiarity of trace elements is the potential to exist as different species (e.g. different oxidation states as in chromium III/chromium VI or arsenic III / arsenic V) and the tendency to form bioavailable metal-organic compounds (e.g. methylmercury or tetramethyl-lead), which effectively determines the bioavailability and toxicity. In practice, most assessments of trace elements measure and report total concentrations (e.g. of chromium) rather than the specific chemical form of the element (e.g. chromium III or chromium VI) due to the complexity of analyses and interpretation of sequential extraction methods in laboratories.

Fluoride, a non-metal contaminant, is a naturally occurring mineral to which the public is often exposed via drinking water. Depending on the dose intake, fluoride may have both beneficial effects (reducing the incidence of dental caries) and negative effects (causing tooth enamel and skeletal fluorosis following prolonged high exposure) (adapted from NCBI, 2020 and WHO, no date), see CH0105.

Iodide contamination poses significant health risks, including thyroid dysfunction and increased cancer risk, particularly from radioactive isotopes like iodine-131. Environmental impacts include disruption of aquatic ecosystems and soil quality degradation. Effective monitoring and management strategies are essential to mitigate these risks and protect both public health and the environment, see CH0105.

Metrics and numeric limits

Guidance values are complex, but in summary, the following may be helpful:

- **Arsenic**: Limits range from 10 µg/L in drinking-water to 0.39 mg/kg in residential soil.
- **Cadmium**: Limits range from 3-5 µg/L in drinking-water to 0.43 mg/kg in residential soil.

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- **Lead**: Limits are typically around 10-15 µg/L in drinking-water and 400 mg/kg in soil.
- **Mercury**: Limits range from 1-6 µg/L in drinking-water to 1.3 mg/kg in residential soil.
- **Chromium**: Limits range from 50-100 µg/L in drinking-water to 0.3 mg/kg for Cr(VI) in residential soil.
- **Fluoride:** The guideline value for fluoride in drinking-water is 1.5 mg/l. In air: the guideline value is 1 µg/m3.
- **Iodide:** The Tolerable Upper Intake Level (UL) for iodine intake for adults is 1,100 micrograms per day. Permissible Exposure Limit, according to OSHA, for iodine in the workplace is 0.1 parts per million. Iodine-131 (a radioactive isotope of iodine) in drinking-water with an MCL of 3 picocuries per liter (pCi/L).

Key relevant UN convention / multilateral treaty

- Basel Convention: Controls transboundary movement of hazardous wastes, including trace elements.
- Rotterdam Convention: Implements prior informed consent for hazardous chemicals, including certain trace elements.
- Stockholm Convention: Focuses on persistent pollutants, including some trace elements.
- Minamata Convention: Specifically targets mercury, a key trace element.
- CLRTAP: Addresses air pollution, including heavy metals like lead, cadmium, and mercury.

Examples of hazard drivers, impacts and risk management

Hazard Drivers of heavy metal/trace element contamination include:

(1) **Industrial Activities;** Example: Mining, quarrying, and smelting of metals can release trace elements such as lead (Pb), cadmium (Cd), and arsenic (As) into the environment.

(2) **Agricultural Practices;** Example: The use of phosphate fertilizers can introduce cadmium (Cd) into soils.

(3) **Urbanization and Infrastructure Development;** Example: Construction activities can lead to increased levels of trace elements such as chromium (Cr) and lead (Pb) from building materials, road construction and waste**.**

(4) Waste Management Practices; Example: Inadequate disposal and treatment of electronic waste and used batteries can release trace elements such as mercury (Hg) and lead (Pb) into the environment.

(5) Climate Change. Example: Increased temperature and precipitation can alter the mobility and bioavailability of trace elements, affecting their distribution and concentration.

(6) Natural Disasters: Example: Flooding can mobilize trace elements from contaminated soils and sediments into water supplies.

Impacts of Heavy Metals and Trace Elements Contamination are:

(1) Environmental Impact; Example: Bioaccumulation of mercury (Hg) in aquatic ecosystems can harm wildlife and disrupt food chains.

(2) Human Health Effects; Example: Chronic exposure to arsenic (As) in drinking-water can lead to skin lesions, cancer, and cardiovascular diseases.

(3) Soil Degradation; Example: Accumulation of cadmium (Cd) in agricultural soils can reduce soil fertility and crop yields.

(4) Economic Impact; Example: Contaminated land may require expensive remediation efforts, affecting property values and development potential.

Multi-hazard Context: The figure below summarises common interactions between heavy metals & trace elements and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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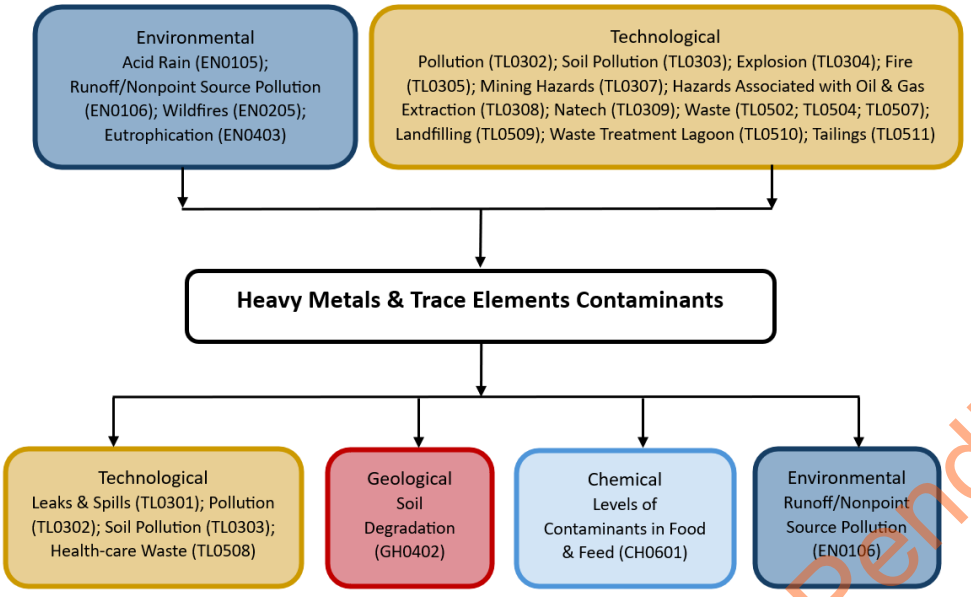

Monitoring: The section and the table below offer an overview of monitoring heavy metals & trace elements. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Water Agencies, Health Agencies, Environmental Agencies, Food & Agriculture Agencies
How is the Hazard Observed/Monitored/Forecast?	Monitoring Technologies can be used to detect heavy metals and trace element levels in water, soil an both in staggered and in real-time; Fixed and portable sensors, such as ion-selective electrodes and spectrophotometers, could provide accurate and continuous measurements for data analysis. Data fro these sensors is collected and analyzed through automated systems, which trigger immediate alerts wh contamination levels exceed the safe threshold.

Risk Management Strategies include:

(1) Regulation and Legislation; Example: The European Union's REACH (Registration, Evaluation, Authorisation, and Restriction of Chemicals) regulation controls the use of hazardous substances, including trace elements.

(2) Pollution Prevention and Control; Example: Implementing best practices in industrial processes to minimize emissions of trace elements.

(3) Environmental Monitoring and Assessment; Example: Regular monitoring of soil, water, and air to detect and quantify trace element contamination.

(4) Remediation and Cleanup; Example: Using phytoremediation to clean up soils contaminated with heavy metals such as cadmium (Cd) and lead (Pb).

(5) Public Awareness and Education; Example: Educating communities about the risks of trace elements and promoting safe practices.

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Coordinating agency or organisation

World Health Organization (WHO), Food and Agriculture Organization of the United Nations (FAO), International Union of Pure and Applied Chemistry (IUPAC)

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CH0101 / CHEMICAL / Heavy Metals and Trace Elements

Arsenic

Definition

Arsenic is a toxic metalloid widely distributed throughout the Earth's crust, generally as arsenic sulphide or as metal arsenates and arsenides. Human exposure to arsenic compounds represents a major public health concern as it has been associated with a range of acute and long-term adverse health effects and diseases (WHO, 2019).

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WHO, 2019. Preventing Disease through Healthy Environments – Exposure to arsenic: A major public health concern. World Health Organization (WHO). apps.who.int/iris/bitstream/handle/10665/329482/WHO-CED-PHE-EPE-19.4.1-eng.pdf?ua=1 Accessed 19 July 2024.

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Annotations

GHS Classification (UNECE, 2023)

Synonyms

As, White arsenic, Arsenious acid, and Fowler's solution.

Additional scientific description

Arsenic (chemical symbol As, atomic number 33) can be released into the atmosphere and water in the following ways: natural activities, such as volcanic activity, dissolution or desorption of minerals (particularly into groundwater), exudates from vegetation and wind-blown dusts; human activities, such as metal smelting, combustion of fossil fuels (especially coal), mining, timber treatment with preservatives and, historically, agricultural pesticide production and use; remobilisation of historic sources, such as mine drainage water; and mobilisation into drinking-water from geological deposits by drilling of tube wells (WHO, 2019). Arsenic compounds have been used as chemical weapons (OPCW, 2024)

In water, arsenic occurs in one of two main forms: arsenite As(III) under reducing conditions and arsenate As(V) if the water is oxygenated. It can be released to the atmosphere, primarily as the trioxide, mainly by high-temperature processes or through volatilisation from aerated soils. In the atmosphere, it is mainly adsorbed onto particles, which are dispersed by winds and deposited on land and water (WHO, 2019).

Soluble inorganic arsenic is highly acutely toxic. Intake of inorganic arsenic over a long period can lead to chronic arsenic poisoning (arsenicosis). Effects, which can take years to develop depending on the level of exposure, include skin lesions, peripheral neuropathy, gastrointestinal symptoms, diabetes, cardiovascular disease, developmental toxicity, and cancer of the skin and internal organs (IARC, 2018). Organic arsenic compounds, which are abundant in seafood, are less harmful to health and are rapidly eliminated by the body.

Human exposure to arsenic and arsenic compounds can occur through environmental or occupational routes. Human

exposure to elevated levels of inorganic arsenic occurs mainly through the intake of groundwater containing naturally high levels of inorganic arsenic, food prepared with this water, and food crops irrigated with high-arsenic water sources. Public health actions need to be continued to reduce human exposure to arsenic, particularly in areas with naturally high levels in groundwater (WHO, 2019).

Metrics and numeric limits

In 2002, the World Health Organization (WHO) reported that at least 140 million people in 50 countries were estimated to have been drinking water containing arsenic at levels above the WHO provisional guideline value of 10 µg/L (WHO, 2019). Inorganic arsenic is naturally present at high levels in the groundwater of several countries, such as Argentina, Chile, China, India (West Bengal), Mexico, the USA, and particularly Bangladesh, where it was estimated that in 2012 approximately 19 million people were exposed to drinking-water concentrations above the national standard of 50 µg/L and 39 million people were drinking water with levels of arsenic above 10 µg/L. In 2010, 21.4% of all deaths in a highly affected area of Bangladesh were attributed to arsenic levels of above 10 µg/L in drinking-water, while another analysis published in 2012 for all districts indicated an annual total of nearly 43,000 deaths (about 5.6% of all deaths) attributable to chronic arsenic exposure (WHO, 2019).

The WHO has published arsenic guidelines for tolerable intake levels, drinking-water and air (WHO, 2019):

- Tolerable daily intake level: In a review of the latest scientific evidence conducted in 2010, the Joint Food and Agriculture Organization of the United Nations (FAO)/WHO Expert Committee on Food Additives (JECFA) determined the lower limit on the benchmark dose for a 0.5% increased incidence of lung cancer (BMDL0.5) from epidemiological data to be 3.0 µg/kg body weight per day (2–7 µg/kg body weight per day based on the range of estimated total dietary exposure). No new tolerable intake level could be established. In areas where levels in water are below the WHO drinking-water guideline value, human health effects are unlikely.
- Drinking-water: The provisional guideline value is 10 µg/L, in light of practical difficulties in removing arsenic in drinking-water, every effort should be made to keep concentrations as low as reasonably possible and below the guideline value when resources are available.
- Air: A safe level of arsenic in air cannot be established.

Key relevant UN convention / multilateral treaty

International Labour Organization C042 - Workmen's Compensation (Occupational Diseases) Convention (Revised), 1934 (ILO, 1934).

Examples of hazard drivers, outcomes and risk management

Hazard Drivers: Drinking-water poses the greatest threat to public health from arsenic (WHO, 2019). Exposure of smokers to arsenic arises from the natural inorganic arsenic content of tobacco. Exposures were higher in the past when tobacco plants were treated with lead arsenate insecticide (WHO, 2019).

Impacts: Most arsenic in industrial processes is used to produce antifungal wood preservatives, which can lead to soil contamination. Other current or historical uses occur within the pharmaceutical and glass industries, in the manufacture of alloys, sheep dips, leather preservatives, arsenic-containing pigments, antifouling paints and poison baits and, to a diminishing extent, in the production of agrochemicals (especially for use in orchards and vineyards). Arsenic compounds are also employed in limited amounts in the microelectronics and optical industries. High arsenic levels in air can be found in the working environment as well as the general environment around non-ferrous metal smelters, where arsenic trioxide may be formed, and some coal-fired power plants (especially those using low-grade brown coal) (WHO, 2019).

In areas where arsenic is not naturally present at high levels, food usually contributes most to the daily intake of arsenic. Fish, shellfish, meat, poultry, dairy products and cereals are the main sources of dietary intake. However, the arsenic in fish and shellfish is usually in the form of organic compounds (e.g., arsenobetaine) that are of low toxicity. In areas where arsenic is naturally present at high levels, food (e.g., rice) prepared with high arsenic-containing water and food crops irrigated with contaminated water also contribute to total daily intake (WHO, 2019).

Accidents involving arsenic have occurred in various contexts, with significant impacts on human health and the environment.

High concentrations of naturally occurring arsenic poisoning in drinking water have resulted in multiple poisoning episodes worldwide. An example from the 1950's and 1960's was the Taiwan Arsenic Poisoning (Blackfoot Disease), which led to the development of a condition known as Blackfoot Disease, characterized by peripheral vascular disease and gangrene. The contamination was traced to artesian well water with high levels of arsenic (Lai, 1994). A second example is the Bangladesh Arsenic Crisis in the 1990s, where a widespread contamination of arsenic from shallow tube wells led to millions being exposed to high levels of arsenic in drinking water and caused various health issues, including skin lesions, cancers (such as skin, lung, and bladder cancer), cardiovascular diseases, and neurological disorders (Smith, 2000).

Chemical spills have had a negative impact on the environment. An example is the Sandoz Chemical Spill which occurred in

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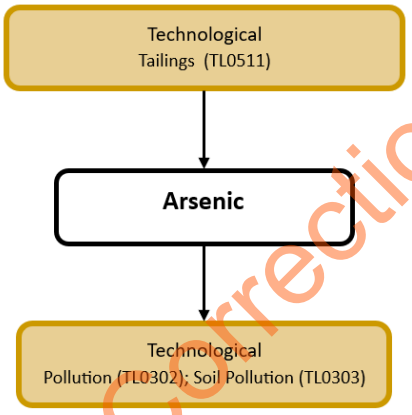
1986. A fire at a Sandoz chemical warehouse in Basel, Switzerland, led to the release of various toxic chemicals, including arsenic compounds, into the Rhine River. The contamination caused widespread fish kills and had significant ecological impacts on the river ecosystem (Capel, 1988).

The historical use of lead arsenate as a pesticide in agriculture led to soil contamination in many regions. Accidental ingestion or inhalation of soil particles containing lead and arsenic residues, particularly by farm workers and children living in treated areas, has resulted in cases of acute poisoning and long-term health effects (Lasky, 1985). The health of inhabitants of communities near mining activities can be affected by arsenic presence. In a region of Colombia where gold mining activities are developed, genotoxicity and mutagenicity in the blood and drinking water of the exposed population were induced by arsenic. The results showed DNA damage related to arsenic in blood ($p < 0.05$) in the exposed population, with arsenic levels above the Agency for Toxic Substances and Disease Registry (ATSDR) limit of 1 µg/L. Mutagenic activity was detected in the drinking water, with only one sample exceeding the WHO's maximum permissible arsenic concentration of 10 µg/L (Calao-Ramos, 2023).

Multi-hazard Context: The figure below summarises common interactions between arsenic and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring arsenic. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	World Health Organization (WHO)
How is the Hazard Observed/Monitored/Forecast?	Sensors and sampling stations to measure arsenic levels in air, water, and soil, coupled with data analysis and modelling to identify contamination trends and predict future risks.

Risk Management: Long-term actions are required to reduce exposure to arsenic from mining, metal smelting and refining, combustion of low-grade coal, pesticide use and timber treatment. In particular, action is needed to reduce the intake of arsenic from drinking-water and food in areas with naturally high levels in the groundwater (WHO, 2019).

The WHO factsheet on preventing disease through healthy environments (WHO, 2019) includes the following risk mitigation recommendations:

- Make available drinking-water with arsenic concentrations below the WHO provisional drinking-water guideline value of 10 µg/L in areas where the level is higher. Possible measures include:
  - Testing water for arsenic levels and informing users of the results.
  - Installing arsenic removal systems, either centralised or domestic, and ensuring appropriate disposal of the removed arsenic.
  - Substituting high-arsenic sources, such as groundwater, with low-arsenic, microbiologically safe sources such as rainwater and treated surface water. Low-arsenic water can be used for drinking, cooking and irrigation purposes, whereas high-arsenic water can be used for other purposes such as bathing and washing clothes.
  - Discriminating between high-arsenic and low-arsenic sources by testing water for arsenic levels and painting tube wells or hand pumps different colours (e.g., red and green).
  - Blending low-arsenic water with higher-arsenic water to achieve an acceptable arsenic concentration level.

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- Reduce occupational exposure to arsenic and its compounds.
- Make both the general public and the health sector aware of the harmful effects of high-arsenic intake and the sources of exposure (including use of high-arsenic water for crop irrigation or food preparation) and how to avoid these sources.
- Monitor high-risk populations for early signs of arsenic poisoning, usually skin problems. It should be noted that total urinary arsenic does not differentiate between inorganic arsenic, which is toxic, and organic arsenic, some of which is not. Where possible, arsenic speciation should be attempted in order to differentiate these two forms (and their metabolites).
- The WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene monitors progress towards global targets on drinking water. In addition, under the new 2030 Agenda for Sustainable Development, the indicator of 'safely managed drinking water services' calls for tracking the population accessing drinking water that is free of faecal contamination and priority chemical contaminants, including arsenic (UN Water, no date; Council of Europe, 2021).

The documented accidents in the impacts section underscore the importance of monitoring and regulating arsenic exposure, implementing safe drinking water practices, and promoting alternative agricultural methods to minimize the risks associated with arsenic contamination.

1. World Health Organization (WHO)
    - Arsenic in Drinking Water: Guidelines and information on the health impacts of arsenic exposure and strategies for prevention.
2. United States Geological Survey (USGS)
    - Arsenic in Groundwater: Information and resources on monitoring arsenic levels in groundwater and surface water across the United States.
    - USGS Arsenic in Groundwater
3. Directive (EU) 2020/2184 of the European Parliament and of the Council of 16 December 2020 on the quality of water intended for human consumption
4. European Commission, Food, Farming, Fisheries, Arsenic in food

Actions to be taken by affected communities to prevent further arsenic exposure for providing safe water for drinking, food preparation, and crop irrigation include:

- Replace high-arsenic sources, like groundwater, with low-arsenic sources, such as rainwater and treated surface water. Use low-arsenic water for drinking, cooking, and irrigation, and high-arsenic water for bathing and washing clothes.
- Identify high-arsenic and low-arsenic sources. Test the water and mark wells or pumps with different colours to indicate arsenic levels. Educate the community for effective use.
- Mix low-arsenic water with higher-arsenic water to reach safe levels.
- Install arsenic removal systems (centralized or domestic) and ensure proper disposal of removed arsenic. Methods include oxidation, coagulation-precipitation, absorption, ion exchange, and membrane techniques. There are more low-cost and effective options available, though long-term effectiveness needs further evidence.

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Coordinating agency or organisation

World Health Organization (WHO).

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0102 / CHEMICAL / Heavy Metals and Trace Elements

Cadmium

Definition

Cadmium is a toxic heavy metal which is widely distributed in the Earth's crust (soil and rocks), air and water; however, human activity has greatly increased levels in environmental media relevant to population exposure. Human exposure to cadmium represents a major public health concern as it has been associated with a range of acute and long-term adverse health effects and diseases (WHO, 2019).

Reference

WHO, 2019. Preventing disease through healthy environments – Exposure to cadmium: A major public health concern. World Health Organization (WHO). https://apps.who.int/iris/bitstream/handle/10665/329480/WHO-CED-PHE-EPE-19.4.3-eng.pdf?ua=1 Accessed 19 July 2024.

Annotations

GHS Classification (UNECE, 2023)

Synonyms

Cd, Cadmium metal, cadmium salts.

Additional scientific description

Cadmium (chemical symbol Cd, atomic number 48) is an element that exists as a number of compounds due to its combining with other elements, including oxygen to form cadmium oxide, chlorine to form cadmium chloride, or sulfur to form cadmium sulfide and cadmium sulfate. Cadmium oxide and cadmium sulfide are most commonly found in the air, whereas cadmium chloride and cadmium sulfate dissolve in water (UK HSA, 2024).

Cadmium is generally present in the environment at low levels; however, human activity has greatly increased levels in environmental media relevant to population exposure. Cadmium can travel long distances from the source of emission by atmospheric transport. It is readily accumulated in many organisms, notably molluscs and crustaceans. Lower concentrations are found in vegetables, cereals and starchy roots (WHO, 2019). Cadmium compounds can be released to the environment in a number of ways, including:

- Natural activities, such as volcanic activity (both on land and in the deep sea), weathering and erosion, and river transport (WHO, 2019).
- Human activities, such as tobacco smoking, mining, smelting and refining of non-ferrous metals, fossil fuel combustion, incineration of municipal waste (especially cadmium-containing batteries and plastics), use of cadmium-containing

Preliminary - Corrections Pending

phosphate fertilisers, and recycling of cadmium-plated steel scrap and electric and electronic waste (WHO, 2019).

- Remobilisation of historic sources, such as the contamination of watercourses by drainage water from metal mines or from waste sites (WHO, 2019).

Cadmium exerts toxic effects on the kidney, the skeletal system and the respiratory system and is classified as a human carcinogen (IARC, 1993). Osteomalacia (softening of the bones) and osteoporosis may occur in those exposed through living or working in cadmium-contaminated areas; for example, in an area of Japan where water and soil were contaminated with cadmium from zinc/lead mines, itai-itai ('ouch-ouch') disease (characterised by osteomalacia, osteoporosis, painful bone fractures and kidney dysfunction) used to be widespread (WHO, 2019).

Human exposure occurs mainly from consumption of contaminated food, active and passive inhalation of tobacco smoke, and inhalation by workers in a range of industries. National, regional and global actions are needed to decrease global environmental cadmium releases and reduce occupational and environmental exposure (WHO, 2019).

Metrics and numeric limits

The World Health Organization (WHO) has published cadmium guidelines for provisional tolerable monthly intake levels, drinking water and air (WHO, 2019).

- Provisional tolerable monthly intake: The Joint Food and Agriculture Organization of the United Nations (FAO)/WHO Expert Committee on Food Additives (JECFA) established a provisional tolerable monthly intake for cadmium in 2010 of 25 µg/kg body weight, based on meta-analysis of epidemiological studies on the relationship between urinary cadmium and beta-2-microglobulin (a marker of renal tubular effects). In light of the long half-life of cadmium in humans, JECFA decided to express the tolerable intake as a monthly value.
- Drinking-water: The guideline for cadmium in drinking-water is 3 µg/L.
- Air: The guideline for cadmium in air is 5 ng/m^3 (annual average).

Key relevant UN convention / multilateral treaty

The UNECE Convention on Long-range Transboundary Air Pollution.Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Cadmium contained in soil and water can be taken up by certain crops and aquatic organisms and accumulate in the food chain. Food constitutes the main environmental source of cadmium for non-smokers (see CH0601 Levels of Contaminants in Food and Feed). Highest cadmium levels are found in the kidney and liver of mammals when fed with cadmium-contaminated feed, and in certain species of oyster, scallop, mussel and crustacean (WHO, 2019).

The tobacco plant naturally accumulates relatively high concentrations of cadmium in its leaves. Thus, smoking tobacco is an important source of exposure and, in the case of heavy smokers, daily intake may exceed that from food. Cigarette smoking can cause significant increases in the concentration of cadmium in the kidney, the main target organ for cadmium toxicity (WHO, 2019).

Inexpensive jewellery, toys and plastics can be significant sources of exposure to cadmium, especially for children; however, many countries have moved to restrict or ban cadmium in such products (WHO, 2019).

In terms of occupational exposure through industrial processes, principal uses are currently in nickel-cadmium batteries, pigments, coatings and plating, as a stabiliser in plastics and other materials (including non-ferrous alloys, semiconductors and photovoltaic devices). The highest potential occupational exposures occur in cadmium production and refining, nickel-cadmium battery manufacture, cadmium pigment manufacture and formulation, cadmium alloy production, mechanical plating, zinc smelting, brazing with silver-cadmium-silver alloy solder and polyvinylchloride compounding (WHO, 2019).

Impacts of cadmium exposure include environmental impacts (soil contamination, particularly near industrial sites; water pollution from leaching; and biodiversity loss); human health impacts (kidney damage from ingestion through food and water; bone damage; respiratory issues; and carcinogenic effects); and economic impacts (agricultural losses from reduced crop yields and quality; and healthcare costs for the human health impacts). Documented accidents involving cadmium have occurred in various industries and settings, leading to significant health and environmental impacts.

One of the most well-known incidents involving cadmium occurred in the Jinzu River basin in Toyama Prefecture, Japan, during the mid-20th century. Widespread mining and industrial activities released cadmium into the river, contaminating rice paddies and water supplies. As a result, residents, particularly women, who consumed cadmium-contaminated rice and water developed severe renal and skeletal abnormalities, known as Itai-Itai Disease.

In the 1910s and 1920s, industrial activities in Toyama Prefecture, Japan, led to the release of cadmium and other heavy

Preliminary – Corrections Pending

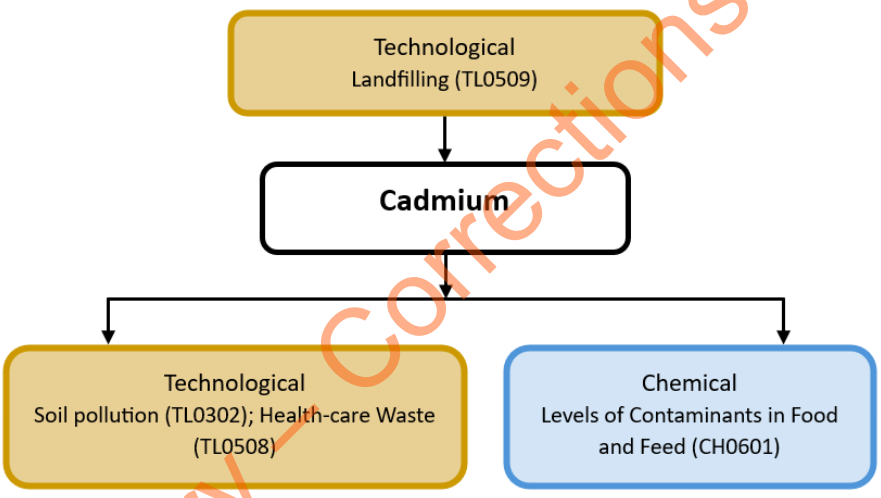
metals into the environment, contaminating soil, water, and crops. This pollution resulted in widespread health problems among residents, including kidney damage and skeletal deformities.

In 2003, in Bangalore, India, the Janaagraha organization discovered lead and cadmium contamination in groundwater sources used by local residents. The contamination was traced to a battery recycling plant in the vicinity. Residents, particularly children, were found to have elevated levels of lead and cadmium in their blood, leading to health concerns and protests against the plant's operations.

Accidental releases of cadmium from industrial facilities, such as metal plating plants, battery manufacturing facilities, and electronic waste recycling operations, have led to localized contamination of air, soil, and water. These incidents can result in acute exposure to cadmium, causing respiratory problems, gastrointestinal issues, and other health effects among workers and nearby residents. (ATSDR, 2012)

These documented accidents underscore the importance of monitoring and regulating cadmium exposure, implementing pollution control measures, and promoting safe handling and disposal practices to prevent adverse health and environmental impacts.

Multi-hazard Context: The figure below summarises common interactions between cadmium and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring cadmium. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	World Health Organization (WHO) Food and Agriculture Organization of the United Nations (FAO).
How is the Hazard Observed/Monitored/Forecast?	Sensors and sampling stations to measure cadmium levels in air, water and soil, coupled with data analysis and modeling to identify contamination trends and predict future risks.

Risk management: The WHO factsheet on preventing disease through healthy environments (WHO, 2019) includes the following risk mitigation recommendations:

- Implement the WHO Framework Convention on Tobacco Control, including providing for protection from exposure to tobacco smoke in indoor workplaces, public transport, indoor public places and, as appropriate, other public places (WHO, 2003).
- Reduce, as far as is practicable, emissions of cadmium – particularly into surface waters – from mining and smelting, waste incineration, application of sewage sludge to the land, and use of phosphate fertilisers and cadmium-containing manure. Develop techniques for the safe disposal of cadmium-containing wastes and effluents.
- Washing fruit and vegetables and peeling roots and tubers can help reduce cadmium contamination.

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- Promote safe and effective measures to increase recycling of cadmium and to restrict non-recyclable uses.
- Promote the elimination of the use of cadmium in products such as toys, jewellery and plastics.
- Reduce cadmium exposure by, for instance, improving working conditions in the non-ferrous metal smelting industry and disseminating information on the proper selection of fertilisers (which sometimes contain high levels of cadmium).
- Raise global awareness on the importance of minimising waste discharges of cadmium.

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Coordinating agency or organisation

World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations.

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0103 / CHEMICAL / Heavy Metals and Trace Elements

Lead

Definition

Lead is a naturally occurring, highly toxic heavy metal. Its widespread use has caused extensive environmental contamination and health problems in many parts of the world. It is a cumulative toxicant that affects multiple body systems, including the neurological, haematological, gastrointestinal, cardiovascular and renal systems. Children are particularly vulnerable to the neurotoxic effects of lead, and even relatively low levels of exposure can cause serious and, in some cases, irreversible neurological damage (WHO, 2024).

Preliminary – Corrections Pending

Reference

WHO, 2024. Lead poisoning. World Health Organization (WHO). Lead poisoning Accessed 2 May 2025.

Annotations

GHS Classification (UNECE, 2023)

Synonyms

Pb, plumbum

Additional scientific description

Lead (chemical symbol Pb, atomic number 82) is found at low levels in the Earth's crust, mainly as lead sulfide (WHO, 2024). Lead has been known since ancient times. It is sometimes found free in nature, but is usually obtained from the ores galena (PbS), anglesite (PbSO4), cerussite (PbCO3) and minum (Pb3O4) (PubChem no date). However, the widespread occurrence of lead in the environment is largely the result of human activity, such as mining, smelting, refining and informal recycling of lead; use of leaded petrol (gasoline); production of lead-acid batteries and paints; jewellery making, soldering, ceramics and leaded glass manufacture in informal and 'cottage' (home-based) industries; electronic waste; and use in water pipes and solder (WHO, 2024). Other sources of lead in the environment include natural activities, such as volcanic activity, geochemical weathering and sea spray emissions, and remobilisation of historic sources, such as lead in soil, sediment and water from mining areas. As lead is a natural element, once it is released into the environment, it persists. Owing to lead's persistence and potential for global atmospheric transport, atmospheric emissions affect even the most remote regions of the world (WHO, 2024).

Acute exposures to lead may cause gastrointestinal disturbances (anorexia, nausea, vomiting, abdominal pain), hepatic and renal damage, hypertension and neurological effects (malaise, drowsiness, encephalopathy) that may lead to convulsions and death. Chronic exposure effects include haematological effects, such as anaemia, or neurological disturbances, including headache, irritability, lethargy, convulsions, muscle weakness, ataxia, tremors and paralysis. Pregnant women are particularly vulnerable; for example, in-utero exposure of the foetus at maternal blood lead levels of less than 5 mg/dL can lead to reduced foetal growth and lower birth rate, and the mother may experience eclampsia and decreased renal function at these blood lead levels. Developing children are particularly vulnerable to lead exposure, with learning disorders and other neurological and developmental disorders occurring at blood lead levels lower than those of adults (US Department of Health and Human Services, 2012).

It has been estimated that lead exposure was responsible, in 2004, for 143,000 deaths and 0.6% of the global burden of disease (expressed in disability-adjusted life years, or DALYs), taking into account mild mental retardation and cardiovascular outcomes resulting from exposure to lead. Young children absorb four to five times as much lead as adults (apart from pregnant women). Infants, young children (especially those less than five years of age) and pregnant women are most susceptible to the adverse effects of lead. The most critical effect of lead in young children is on the developing nervous system. Subtle effects on intelligence quotient (IQ) are expected from blood lead levels at least as low as 5 µg/dL (50 µg/L), and the effects gradually increase with increasing levels of lead in blood (WHO, 2024).

Metrics and numeric limits

The World Health Organization (WHO) has published lead guidelines for drinking-water and air (WHO, 2024): Drinking-water: 10 µg/L. Air: 0.5 µg/m^3 (annual average).

Key relevant UN convention / multilateral treaty

International Labour Organisation C013 - White lead (painting) convention, 1921 (ILO, 1921).

Examples of hazard drivers, impacts and risk management

Hazard Drivers. Significant sources of exposure to lead still remain, particularly in developing countries (WHO, 2024).

Further efforts are required to continue to reduce the use and release of lead and to reduce environmental exposures, particularly for children and women of child-bearing age (WHO, 2024). Recent reductions in the use of lead in petrol (gasoline), paint, plumbing and solder have resulted in substantial reductions in lead levels in the blood.

In terms of industrial processes, lead is used mainly in the production of lead-acid batteries, plumbing materials and alloys. Other uses are in cable sheathing, paints, glazes and ammunition. Mining, smelting, and informal processing and recycling of electric and electronic waste can also be significant sources of exposure. Lead has been used widely in the form of tetraethyl and tetramethyl lead as antiknock and lubricating agents in petrol, although the majority of lead is emitted from vehicles in the form of inorganic particles. This use has been phased out in most countries, which has resulted in a significant reduction of human exposure and mean blood lead levels. In the few parts of the world where leaded petrol is still in use, however, it continues to be a major source of exposure. Old industrial hotspots that have not been cleaned up can also represent a hazard.

Impacts. Even years after contamination has stopped, particularly to children who might ingest contaminated soil or dust as a result of their hand-to-mouth behaviour and pica (WHO, 2024).

For the non-smoking general population, the largest contribution to the daily intake of lead is from the ingestion of food, dirt and dust. The amount of lead in food plants depends on soil concentrations and is highest around mines and smelters. Cereals can contain high levels of lead, and spices may be contaminated with lead. Use of lead-soldered food and beverage cans (which is now diminishing) may considerably increase the lead content of the food or beverage, especially in the case of acidic foods or drinks. As fruit juices and various alcoholic drinks tend to be acidic, the use of any lead-containing products in their manufacture, distribution or storage will raise lead levels. Migration of lead into food from lead-glazed ceramic or pottery dinnerware is also a source of exposure. Smoking tobacco increases lead intake (WHO, 2024).

Lead present at elevated levels in tap water is rarely the result of its dissolution from natural sources but is often due to old household plumbing systems containing lead pipes, solder and fittings. Soft acidic water dissolves the most lead (WHO, 2024).

Contaminated dust may be the main source of exposure for infants in countries that no longer use leaded petrol. The weathering, peeling or chipping of lead-based paints, mainly found in older houses, plays a role in children's

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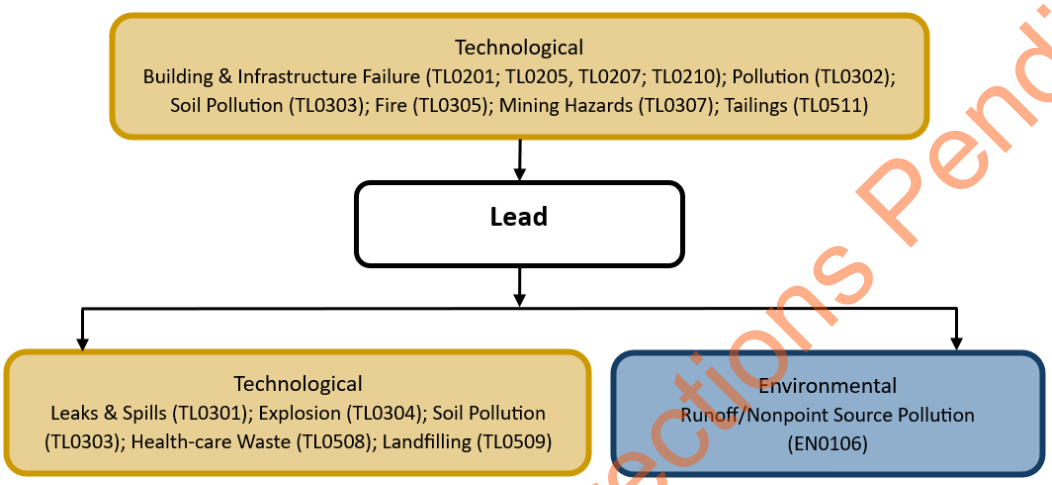
exposure, especially as some young children eat the fragments or lick dust-laden fingers. Lead-containing dust may be brought into the home on the clothes of those who work in industries where such dust is generated. Some toys are either made from lead or contain lead (e.g., some plastics or paints). Some traditional medicines and makeup (e.g., kohl) contain lead (WHO, 2024).

Primary prevention (i.e., the elimination of exposure to lead at its source) is the single most effective intervention against childhood lead poisoning (WHO, 2024).

Multi-hazard Context: The figure below summarises common interactions between lead and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring lead. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Water agencies, Environmental agencies, health agencies
How is the Hazard Observed/Monitored/Forecast?	Monitoring the level of lead in dust, soil and tap water

Risk Management. The following actions for eliminating use are needed:

- Phase out the use of lead additives in motor fuels in countries where this has not yet been done.
- Phase out the use of lead in paints on a worldwide basis.
- Eliminate the use of leaded solder in food and drink cans, as well as in water pipes.
- Eliminate the use of lead in homes, schools, school materials and children's toys.
- Eliminate the use of lead glazing for pottery intended for cooking, eating or drinking.
- Encourage the removal of plumbing and fittings containing lead (as this is costly, other measures, such as corrosion control and minimising the dissolving of lead in water systems, should be implemented in the meantime).
- Identify and eliminate lead use in traditional medicines and cosmetics.
- Establish sentinel systems that include human biomonitoring, possibly most easily facilitated via a network of recognised analytical laboratories.
- The WHO provides recommendations (WHO, 2024) on preventing exposure to lead from electric and electronic waste (e.g., lead-acid batteries, computers), particularly for children, which include:
    - Ensure that the recycling of lead-containing waste is undertaken only in the presence of appropriate industrial hygiene measures and that informal recycling and use of lead-containing waste are discouraged.

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- Identify contaminated sites and take necessary action to prevent human exposure to lead from these areas.
- Prevent pica of paint chips in homes previously painted with lead-based paint.
- Follow good practices, including personal protective equipment and barriers, during rehabilitation, deconstruction, decommissioning, and other work in and near buildings and structures that may have been painted with lead-based paint.

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Coordinating agency or organisation

World Health Organization (WHO).

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0104 / CHEMICAL / Heavy Metals and Trace Elements

Mercury

Definition

Mercury is a naturally occurring element that is found in air, water and soil. Exposure to mercury, even small amounts, may cause serious health problems and is a threat to the development of the foetus in utero and for children early in life (WHO, 2021).

Reference

WHO, 2024. Mercury (WHO). Mercury Accessed 2 May 2025.

Annotations

GHS Classification (UNECE, 2023)

Synonyms

Hg, Quicksilver, Hydrargyrum, Elemental Mercury, Metallic Mercury, Liquid Mercury, Azogue, and Cinnabar

Additional scientific description

Mercury (chemical symbol Hg, atomic number 80) exists in various forms: elemental mercury (metallic or vapour) and inorganic mercury compounds (to which people may be exposed, for example, through their occupation); and organic (or organometallic) mercury compounds (for example, methylmercury, to which people may be exposed through their diet). These forms of mercury differ in their degree of toxicity and toxic effects (WHO, 2021).

Mercury occurs naturally in the Earth's crust (UNEP, 2018). It is released into the environment from volcanic activity, weathering of rocks and as a result of human activity. Human activity is the main cause of mercury releases, particularly coal-fired power stations, residential coal burning for heating and cooking, industrial processes, waste incinerators and as a result of mining for mercury, gold and other metals (WHO, 2021). Mercury has been used in dental amalgam for tooth fillings. Methylmercury has a history as a fungicide. Organic mercury compounds are used as protective agents in biochemistry.

Mercury may have toxic effects on the nervous, digestive and immune systems, and on the lungs, kidneys, skin and eyes. The World Health Organization considers mercury to be one of the top ten chemicals or groups of chemicals of major public health concern. People are mainly exposed to mercury in the form of methylmercury, an organometallic compound, when they eat fish and shellfish that contain this compound (WHO, 2021).

Once in the environment, elemental mercury can be transformed into methylmercury and consumed by phytoplankton in seawater and by sulphate-reducing bacteria in freshwater sediments. Methylmercury then bioaccumulates (the process by which an organism contains progressively higher concentrations of the substance than its surroundings) in fish and shellfish. Methylmercury also biomagnifies up food chains: for example, large predatory fish are more likely to have high levels of methylmercury as a result of eating many smaller fish that have acquired methylmercury through ingestion of plankton (WHO, 2021).

Use of elemental mercury in some traditional therapies, religions and practices (e.g., Santería, Espiritismo) represents a risk of exposure due to the practice itself or from accidental spills. However, the extent of the problem is unknown. Use of mercury-containing beauty creams, hair treatment and other cosmetic products may cause significant exposure (WHO, 2021).

Health effects from mercury (WHO, 2021) are summarised as follows:

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- Inhalation of mercury vapour can produce harmful effects on the nervous, digestive and immune systems, lungs and kidneys, and may be fatal. The inorganic salts of mercury are corrosive to the skin, eyes and gastrointestinal tract, and may induce kidney toxicity if ingested.
- Neurological and behavioural disorders may be observed after inhalation, ingestion or dermal application of different mercury compounds. Symptoms include tremors, insomnia, memory loss, neuromuscular effects, headaches and cognitive and motor dysfunction. Mild subclinical signs of central nervous system toxicity can be seen in workers exposed to an elemental mercury level in the air of 20 µg/m^3 or more for several years. Kidney and immune effects have been reported. There is no conclusive evidence linking mercury exposure to cancer in humans.
- Children are especially vulnerable to mercury and may be exposed directly by eating contaminated fish. Methylmercury bioaccumulates in fish and if consumed by pregnant women may lead to neurodevelopmental problems in the developing foetus. Transplacental exposure is the most dangerous, as the foetal brain is very sensitive. Neurological symptoms include mental retardation, seizures, vision and hearing loss, delayed development, language disorders and memory loss. In children, a syndrome characterised by red and painful extremities called acrodynia has been reported to result from chronic mercury exposure.

Metrics and numeric limits

Guidance values are complex, but in summary, the following may be helpful:

- Drinking-water: 0.006 mg/L (6 µg/L) for inorganic mercury (WHO, 2011).
- Provisional tolerable weekly intake: for methylmercury in food of 1.6 µg/kg body weight (JECFA, 2007).
- Air: lowest-observed-adverse-effect level (LOAELs) for mercury vapour are around 15–30 µg/m^3 (WHO, 2000).

Key relevant UN convention / multilateral treaty

Minamata Convention on Mercury (UNEP, 2013).

Examples of hazard drivers, impacts and risk management

Hazard Drivers. Mercury is emitted to the atmosphere by (a) primary anthropogenic sources, including artisanal and small-scale gold mining (ASGM), fossil fuel combustion, and metal smelting; (b) re-emissions of historical anthropogenic ("legacy") Hg from ocean and land; and (c) geogenic sources.

Impacts. All humans are exposed to mercury. Factors that determine whether health effects occur, and their severity include: the chemical form of mercury concerned; the dose; the age or developmental stage of the person exposed (the foetus is most susceptible); the duration of exposure; and the route of exposure (inhalation, ingestion or dermal contact) (WHO, 2021).

Generally, two groups are more sensitive to the effects of mercury. Foetuses are most susceptible to developmental effects due to mercury potentially leading to impaired neurological development with cognitive thinking, memory, attention, language, and fine motor and visual spatial skills affected. The second group is people who are regularly exposed (chronic exposure) to high levels of mercury (such as populations that rely on subsistence fishing or people who are occupationally exposed). Among selected subsistence fishing populations, between 1.5/1000 and 17/1000 children showed cognitive impairment (mild mental retardation) associated with the consumption of fish containing mercury (WHO, 2021).

A significant example of mercury exposure affecting public health occurred in Minamata, Japan, between 1932 and 1968, where a factory producing acetic acid with a mercury catalyst discharged inorganic mercury into Minamata Bay. The bay was rich in fish and shellfish, providing the main livelihood for local residents and fishermen from other areas. For many years, no one realised that the fish were contaminated with mercury, and that it was causing a strange disease in the local community and in other districts. At least 50,000 people were affected to some extent and more than 2000 cases of Minamata disease were certified. Minamata disease peaked in the 1950s, with severe cases suffering brain damage, paralysis, incoherent speech and delirium. The continued release of mercury into the environment from human activity, the presence of mercury in the food chain, and the demonstrated adverse effects on humans are of such concern that in 2013, governments agreed to the Minamata Convention on Mercury. The Convention obliges Parties to take a range of actions, including to address mercury emissions to air and to phaseout certain mercury-containing products (WHO, 2019).

Documented accidents involving mercury have occurred in various industries and settings, leading to significant health and environmental impacts.

Accidental spills or releases of mercury, particularly in industrial settings such as chemical plants, laboratories, and gold mining operations, can lead to contamination of air, soil, and water. Exposure to mercury vapor or ingestion of mercury-contaminated food or water can cause acute poisoning, with symptoms including respiratory problems, neurological disorders, and gastrointestinal issues (ATSDR, 2022).

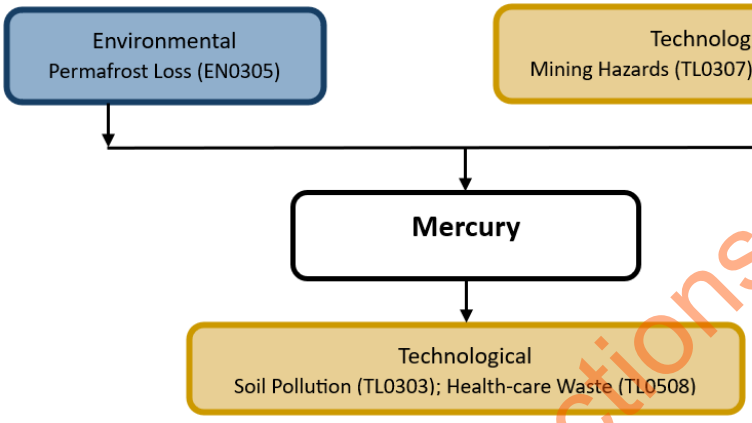
Improper handling and disposal of mercury-containing dental amalgam waste have led to environmental contamination and

Preliminary – Corrections Pending

health risks for dental professionals and patients. Mercury released from dental amalgam fillings during placement, removal, or cremation can contribute to environmental pollution and human exposure.

Artisanal and Small-Scale Gold Mining (ASGM): Mercury is often used in ASGM to extract gold from ore. Improper handling and disposal of mercury during gold extraction processes can lead to environmental contamination, particularly in water bodies. ASGM communities and workers are at risk of mercury exposure, resulting in health problems such as neurological disorders, kidney damage, and developmental issues in children (Spiegel et al., 2018).

Multi-hazard Context: The figure below summarises common interactions between mercury. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring mercury. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	The United Nations Environment Programme (UNEP) works on global initiatives to red mercury emissions and exposure.
How is the Hazard Observed/Monitored/Forecast?	The Global Mercury Observation System (GMOS) is an early warning system designe monitor mercury levels in the environment.

Risk Management: There are several ways to prevent adverse health effects of mercury, including promoting clean energy, stopping the use of mercury in gold mining, eliminating the mining of mercury and phasing out non-essential mercury-containing products.

- Promote the use of clean energy sources that do not burn coal. Burning coal for power and heat is a major source of mercury. Coal contains mercury and other hazardous air pollutants that are emitted when the coal is burned in coal-fired power plants, industrial boilers and household stoves (WHO, 2021).
- Eliminate mercury mining and use of mercury in gold extraction and other industrial processes. Mercury is an element that cannot be destroyed; therefore, mercury already in use can be recycled for other essential uses, with no further need for mercury mining. Mercury use in artisanal and small-scale gold mining is particularly hazardous, and health effects on vulnerable populations are significant. Non-mercury (non-cyanide) gold-extraction techniques need to be promoted and implemented, and where mercury is still used, safer work practices need to be employed to prevent exposure (WHO, 2021).
- Phase out use of non-essential mercury-containing products and implement safe handling, use and disposal of remaining mercury-containing products including batteries, measuring devices, such as thermometers and barometers, electric switches and relays in equipment, lamps (including some types of light bulbs), dental amalgam (for dental fillings), skin lightening products and other cosmetics and pharmaceuticals (WHO, 2021).
- Establish a sentinel system to detect hazardous substances.

Key aspects of mercury risk management include:

Objectives:

1. Monitoring: Track mercury levels in air, water, soil, and biota (plants and animals).
2. Data Collection: Gather data on mercury emissions from various sources, including natural sources like volcanic activity

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and anthropogenic sources like industrial processes.

3. Risk Assessment: Assess the risk posed by mercury exposure to human health and the environment.
4. Policy Support: Provide data to inform and support policies aimed at reducing mercury emissions and exposure.

Components:

1. Sensors and Sampling Stations: Deploy sensors and sampling stations globally to continuously measure mercury concentrations.
2. Data Analysis: Use advanced analytical techniques to interpret the collected data and identify trends.
3. Modelling: Develop models to predict the dispersion and deposition of mercury in the environment.
4. Reporting and Communication: Communicate findings to stakeholders, including governments, environmental agencies, and the public.

Challenges:

1. Coverage: Ensuring comprehensive global coverage to accurately monitor mercury levels in different regions.
2. Accuracy: Maintaining the accuracy and reliability of data collected from various sources.
3. Collaboration: Coordinating efforts among multiple countries and organizations to create a unified monitoring system.
4. Response: Developing effective response strategies to mitigate the impact of mercury exposure.

Importance:

1. Health Impact: Mercury exposure can lead to serious health issues, including neurological and developmental problems, particularly in children and foetuses.
2. Environmental Impact: Mercury can bioaccumulate in the food chain, affecting wildlife and ecosystems.
3. Policy Development: Accurate data on mercury levels is essential for creating effective environmental policies and regulations.

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Coordinating agency or organisation

Preliminary – Corrections Pending

World Health Organization (WHO), Food and Agriculture Organization of the United Nations (FAO), International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0105 / CHEMICAL / Heavy Metals and Trace Elements

Fluoride and Iodine/Iodide Excess or Inadequate Intake

Definition

Fluoride is a naturally occurring mineral to which the public is often exposed via drinking water. Depending on dose intake, fluoride may have beneficial effects (reducing the incidence of dental caries) or negative effects (causing tooth enamel and skeletal fluorosis following prolonged high exposure) (adapted from NCBI, 2020 and WHO, no date). Some water supplies are fluoridated in order to achieve improved dental health.

Iodine is a non-metallic element essential for the human body, as it is a crucial component of thyroid hormones, which regulate various metabolic processes, including growth and energy expenditure. Iodine, usually as iodide salts in the diet, is absorbed throughout the gastrointestinal tract. Iodine is essential for healthy brain development in the foetus and young child. A deficiency in iodine can lead to thyroid gland problems, such as goitre and hypothyroidism. Iodine deficiency negatively affects the health of women, as well as economic productivity and quality of life (WHO, 2023). Food fortification (often with potassium iodide, KI) is sometimes used to address iodine deficiency.

Preliminary – Corrections Pending

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Annotations

GHS Classification (UNECE, 2023)

Synonyms

Fluoride: Fluorine Ion, Fluoride Ion, Hydrogen Fluoride (HF), Sodium Fluoride (NaF), Calcium Fluoride (CaF_2), Fluoride Salt.

Iodine: Elemental Iodine, Iodide (I^-), Iodate (IO_3^-), Iodine Solution, Lugol's Solution, Iodophor.

Additional scientific description

Fluorine and iodine, together with chlorine, bromine, astatine and tennessine are elements from Group 17 in the Periodic Table, also known as the Halogen family. Halides, the anions from Group 17 such as **fluoride**, chloride, bromide, **iodide,** etc., are considered additionally as phytotoxic air pollutants and can have a severe impact on health at high or low concentrations.

Fluoride is the anion (negatively charged ion with the symbol "F^-" of fluorine (chemical element with the symbol "F" and atomic number 9), and it is found in various forms, both in nature and in synthetic products. Fluoride can be released into the environment in several ways: (i) natural activities, such as volcanic emissions, weathering of minerals and dissolution, particularly into groundwater; (ii) human activities, such as the production and use of phosphate fertilizers; manufacture and use of hydrofluoric acid and production of aluminium, steel and oil; and (iii) remobilization of historic sources, such as water flow and sediment movement from aluminium production plants.

The beneficial effect of fluoride includes the minimization of tooth decay and caries. Public health action to provide sufficient fluoride intake can be achieved through drinking water fluoridation or, when this is not possible, through salt or milk fluoridation or use of dental care products containing fluoride (WHO, no date).

Excessive fluoride intake usually occurs through the consumption of groundwater naturally rich in fluoride, particularly in warm climates where water consumption is greater, or where high-fluoride water is used in food preparation or irrigation of crops such as rice. In these areas, measures should be sought to manage intakes by providing drinking-water with a moderate (i.e., safe) fluoride level or using alternative sources of water for drinking, cooking or irrigation. The preparation of food using fluoride-rich coal also contributes to excessive fluoride intake via ingestion and inhalation (WHO, 2019).

Iodine is a chemical element with the symbol "I" and atomic number 53. Iodine is essential for healthy brain development in the foetus and young children. Iodine deficiency negatively affects the health of women, as well as economic productivity and quality of life. Iodine's physiologic role in the human body is in the synthesis of thyroid hormones by the thyroid gland. Dietary iodine is converted into the bio-available iodide ion "I^-" before it is absorbed from food and water, enters the circulation as plasma inorganic iodide, which is cleared from circulation by the thyroid and kidney. Excess iodide is excreted by the kidney in urine. For determining the iodine requirements, the important indexes are serum T_4 and TSH levels (indicating normal thyroid status) and urinary iodine excretion (FAO 2002).

Most people need an additional source of iodine as it is found in relatively small amounts in the diet. Iodization is the process of fortifying salt for human consumption with iodine and is an effective strategy to increase iodine intake at the population level. Monitoring the levels of iodine in salt and the iodine status of the population is critical for ensuring that the population's needs are met and not exceeded.

Iodine contamination poses significant health risks, including thyroid dysfunction and increased cancer risk, particularly from radioactive isotopes like iodine-131 (CDC, 2024). Environmental impacts include disruption of aquatic ecosystems and soil quality degradation (Cox et al. 2014). Effective monitoring and management strategies are essential to mitigate these risks and protect both public health and the environment.

Metrics and numeric limits

Fluoride

World Health Organization (WHO) fluoride guideline values (WHO, 2019):

Drinking water: The guideline value for fluoride in drinking water is 1.5 mg/L, based on increasing risk of dental fluorosis at higher concentrations and that progressively higher levels of fluoride lead to increasing risk of skeletal fluorosis. This value is higher than that recommended for artificial fluoridation of water supplies for the prevention of dental caries, which is usually 0.5–1.0 mg/L. The WHO recommends that, in setting a standard, Member States should take into account drinking water consumption and fluoride intake from other sources.

Air: The guideline value is 1 µg/m^3 (developed to prevent effects on livestock and plants and is also considered sufficiently protective of human health).

Preliminary – Corrections Pending

Iodine / Iodide

World Health Organization (WHO) iodine deficiency values. From: Vitamin and Mineral Nutrition Information System (VMNIS). Micronutrients database (http://www.who.int/vmnis/database/en/) Accessed 31 July 2024.

Iodine deficiency measured by median urinary iodine concentration (µg/L) in school-age children (≥6 years): <20 µg/L – Insufficient - Severe deficiency, 20-49 µg/L – Insufficient - Moderate deficiency, 50-99 µg/L – Insufficient - Mild deficiency, 100-199 µg/L – Adequate, Adequate iodine nutrition, 200-299 µg/L - Above requirements - May pose a slight risk of more than adequate iodine intake in these populations, ≥300 µg/L – Excessive - Risk of adverse health consequences (e.g. iodine-induced hyperthyroidism or autoimmune thyroid disease).

Iodine deficiency measured by median urinary iodine concentration (µg/L) in pregnant women: <150 µg/L – Insufficient, 150-249 µg/L – Adequate, 250-499 µg/L - Above requirements, ≥500 µg/L – Excessive. Iodine deficiency measured by median urinary iodine concentration (µg/L) in lactating women and children aged <2 years: <100 µg/L – Insufficient, ≥100 µg/L – Adequate

Key relevant UN convention / multilateral treaty

The World Health Organization (WHO), United Nations Children's Fund (UNICEF), and other international bodies advocate for universal salt iodization (USI) as a strategy to eliminate iodine deficiency disorders (IDD) globally.

Examples of hazard drivers, impacts and risk management

Hazard Drivers

Fluoride contamination: Natural Sources: Geological Activity and Hot Springs. Anthropogenic (Human-Caused) Sources: Industrial Processes, Agricultural Activities, and Coal Burning.

Iodine contamination: Natural Sources: Geological Activity and Hot Springs. Anthropogenic (Human-Caused) Sources: Industrial Processes, Agricultural Activities, and Coal Burning. In addition, iodine release into the atmosphere could occur from volcanic eruptions, which eventually deposits onto land and water bodies. Iodine-131, a radioactive isotope of iodine, can be released during nuclear accidents or improper disposal of nuclear waste, leading to contamination of air, soil, and water.

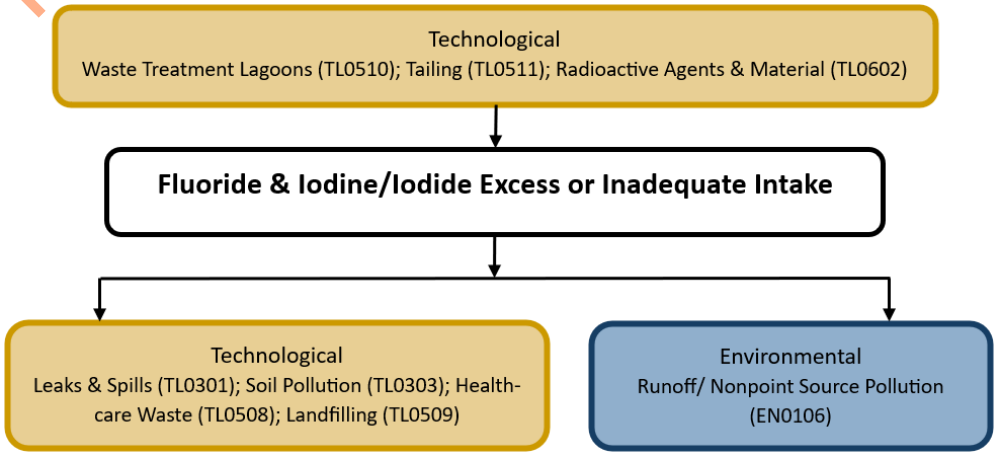
Impacts

Fluoride contamination: Two worldwide public health concerns related to fluoride need to be addressed: the need to reduce dental caries and the need to mitigate the effects of excessive fluoride intake. Thus, public health actions are required to provide sufficient fluoride intake where this is lacking, to minimize tooth decay, as well as to provide drinking water with a moderate (i.e., safe) fluoride level in areas where groundwater contains high fluoride levels (WHO, 2019).

To provide guidance on the need to control population exposure to fluoride and establish the balance between caries prevention and protection against adverse effects of fluoride, community health programmers can estimate total exposure by measuring renal fluoride excretion and compare these levels with established optimal levels using methods published by the WHO. However, risk mitigation measures implemented should also take into consideration local contexts and sensitivities (WHO, 2019).

Iodine contamination on human health: Thyroid Dysfunction: Both excessive and insufficient iodine intake can disrupt thyroid function. Excessive iodine can lead to hyperthyroidism, while insufficient iodine can cause hypothyroidism and goitre. Iodine Toxicity: Acute iodine toxicity can result from high levels of iodine intake, leading to symptoms such as abdominal pain, vomiting, and diarrhoea. Chronic exposure to high iodine levels may cause more severe health issues, including thyroiditis and thyroid cancer. Radioactive Iodine Exposure: Exposure to iodine-131 from nuclear accidents can increase the risk of thyroid cancer, particularly in children.

Multi-hazard Context: The figure below summarises common interactions between fluoride and Iodine/iodide excess or inadequate intake and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Preliminary – Corrections Pending

Monitoring: The section and the table below offer an overview of monitoring fluoride and Iodine/iodide excess or inadequate intake. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	World Health Organization (WHO): "Guidelines for Drinking-water Quality". Food and Agriculture Organization of the United Nations (FAO): "Global assessment of soil pollution Report". Environmental Protection Agency (EPA): "National Primary Drinking Water Regulations".
How is the Hazard Observed/Monitored/Forecast?	WHO provides comprehensive guidelines on the permissible levels of various contaminants, including fluoride and iodide, in drinking water to ensure safety and health. EPA sets standards for drinking water contaminants, including fluoride and iodide, under the Safe Drinking Water Act. These regulations ensure the safety of public drinking water supplies in the United States.

Risk Management:

The WHO recommends (WHO, 2019) that the following actions are required to provide adequate fluoride or control excess through the following measures.

Inadequate fluoride intake:

- Fluoridating low-fluoride drinking water where practicable, as well as considering alternatives, such as salt or milk fluoridation.
- Reduce the incidence of dental caries by: Developing effective and affordable fluoridated toothpastes for use in developing countries. Promoting optimal oral hygiene, based on the use of effective fluoridated toothpaste, guidance on the amount of fluoridated toothpaste to and exposure to other sources of fluoride in the community. Supporting the use of silver diamine fluoride and atraumatic restoration treatment, and other minimally invasive techniques, using glass ionomer cement to stabilize caries lesions.

Irrespective of fluoride exposure, advocating a low-sugar diet in accordance with the WHO recommendation that free (added) sugars should not exceed 10% of total energy intake by both adults and children (strong recommendation); the WHO further suggests a reduction to below 5% of total energy intake (conditional recommendation).

Excess fluoride:

- Where practicable, monitor the prevalence of enamel fluorosis using scoring guidance systems such as those developed by the WHO.
- Provide drinking water with fluoride levels that do not produce adverse health effects, by:
  - Seeking alternative water sources in areas with fluoride-rich groundwater, particularly where water consumption is high due to elevated temperatures.
  - Defluoridation of water for drinking and cooking, where an alternative source is not an option, using methods such as bone charcoal adsorption, contact precipitation, coagulation–flocculation/ sedimentation using aluminum sulphate (Nalgonda process), activated alumina adsorption and clay considering local context. Research the appropriateness of community fluoridation schemes in view of natural fluoride levels in water. Water Treatment Technologies for iodine removal include activated carbon filtration, reverse osmosis, ion exchange or alternative water sources.
- Setting Standards: Governments and regulatory bodies should establish and enforce guidelines for maximum allowable fluoride levels in drinking water and industrial emissions.
- Monitor fluoride levels in the environment, especially in areas where there is exposure to elevated fluoride levels due to human activities and determine the overall exposure to fluoride.
- Encourage mothers to breastfeed, even in areas with high fluoride intake, because breast milk is optimal for infant health and usually low in fluoride.

Discourage the use of fluoride-rich coal for cooking purposes.

The WHO recommends (WHO, 2019) that the following actions are required to provide adequate iodine or control excess through the following measures:

Inadequate iodine intake:

- Awareness and Education: Public health campaigns can educate communities on the risks of iodine contamination, safe iodine intake levels, and the importance of proper monitoring.
- Iodine Supplementation Programs: In regions where iodine deficiency is a concern, carefully managed iodine supplementation programs can help ensure adequate iodine intake without exceeding safe levels.

Excess iodine:

- Monitor iodine levels in the environment, especially in areas where there is exposure to elevated iodine levels due to human activities and determine the overall exposure to iodine.

Preliminary – Corrections Pending

- Implement Nuclear Safety Regulations: Stricter regulations and safety measures should be in place to prevent the release of radioactive iodine from nuclear facilities and ensure proper disposal of nuclear waste.

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Coordinating agency or organisation

Preliminary – Corrections Pending

World Health Organization (WHO), Food and Agriculture Organization of the United Nations (FAO).

Preliminary – Corrections Pending

CH0201 / CHEMICAL / Carcinogens

Aflatoxins

Definition

Aflatoxins are mycotoxins – toxic compounds that are naturally produced by certain types of mould (fungi). Aflatoxins are among the most poisonous mycotoxins and are produced by certain moulds (Aspergillus flavus and A. parasiticus) that grow in soil, decaying vegetation, hay, and grains. Aflatoxins pose a serious health risk to humans and livestock (WHO, 2023).

References

WHO, 2023. Mycotoxins. World Health Organization (WHO). www.who.int/news-room/fact-sheets/detail/mycotoxins Accessed 12 May 2024.

Annotations

GHS Classification

Synonyms

mycotoxins; aspergillus toxins; fungal toxins; foodborne toxins; carcinogenic mycotoxins

Additional scientific description

Aflatoxins are among the most poisonous of the mycotoxins and place communities as well as individuals at risk. Mycotoxins are toxic compounds that are naturally produced by certain types of mould (fungi). Moulds that can produce mycotoxins grow on many foodstuffs such as cereals, dried fruits, nuts and spices (see CH0601). Mould growth can occur either before harvest or after harvest, during storage, on/in the food itself, often under warm, damp and humid conditions. Most mycotoxins are chemically stable and survive food processing (WHO, 2023).

Aflatoxins are difuranocoumarin derivatives with a bifuran group attached to one side of the coumarin nucleus and either a pentanone ring (B series) or a six-membered lactone ring (G series) on the other side. Major types include: Aflatoxin B1 (AFB1) and B2 (AFB2), Aflatoxin G1 (AFG1) and G2 (AFG2), and Aflatoxin M1 (AFM1) and M2 (AFM2).

Several hundred different mycotoxins have been identified, but the most commonly observed mycotoxins that present a concern to human health and livestock include aflatoxins, ochratoxin A, patulin, fumonisins, zearalenone and nivalenol/deoxynivalenol. Mycotoxins appear in the food chain as a result of mould infection of crops both before and after harvest. Exposure to mycotoxins can happen either directly by eating infected food or indirectly from animals that are fed contaminated feed, especially from milk (WHO, 2023).

Aflatoxins are produced by certain moulds (Aspergillus flavus and A. parasiticus) which grow in soil, decaying vegetation, hay, and grains and the crops that are frequently affected by Aspergillus spp. include cereals (corn, sorghum, wheat, rice), oilseeds (soybean, peanut, sunflower, cotton seeds), spices (chili peppers, black pepper,

Preliminary – Corrections Pending

coriander, turmeric, ginger) and tree nuts (pistachio, almond, walnut, coconut, Brazil nut). Large doses of aflatoxins can lead to acute poisoning (aflatoxicosis) and can be life-threatening, usually through damage to the liver (WHO, 2023). Aflatoxins have been classified as human carcinogens by the International Agency for Research on Cancer (IARC, 2002). Aflatoxins are a particular concern for Africa (WHO, no date).

Metrics and numeric limits

The United Nations food standards body Codex Alimentarius Commission has set the maximum levels for aflatoxin in foods, including various nuts, grains, dried figs and milk (in the range 0.5-15 µg/kg; a microgram is one billionth of a kilogram) (WHO, 2023).

EU 2006: 2 µg/kg for aflatoxin B1 in nuts and dried fruits intended for direct human consumption; 4 µg/kg for total aflatoxins (B1, B2, G1, G2) in nuts and dried fruits.

Codex Alimentarius: 10 µg/kg for total aflatoxins in peanuts intended for further processing; 15 µg/kg for total aflatoxins in other nuts intended for further processing.

Key relevant UN convention / multilateral treaty

Codex Alimentarius (FAO/WHO, no date).

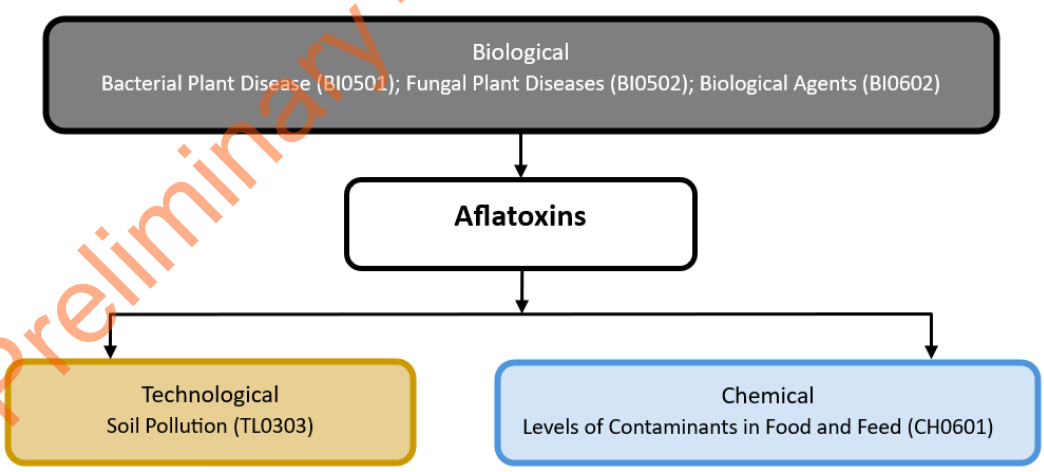
Examples of hazard drivers, impacts and risk management

Hazard Drivers: Mould growth on food and the conditions that promote it are key drivers of aflatoxin poisoning events. Any event that increases consumption of decaying or contaminated food may increase the incidence of aflatoxin poisoning. Thus famines, or events that cause them (e.g. weather events) may increase this risk.

Impacts: Large doses of aflatoxins lead to acute poisoning (aflatoxicosis) that can be life-threatening, usually through damage to the liver. Outbreaks of acute liver failure (jaundice, lethargy, nausea, death), identified as aflatoxicosis, have been observed in human populations since the 1960s. Chronic exposure is responsible for a significant fraction of liver cancer cases in Africa (WHO, no date).

Aflatoxins also pose a significant economic threat (WHO, no date).

Multi-hazard Context: The figure below summarises common interactions between aflatoxins and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring aflatoxins. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	World Health Organization, Food and Agriculture Organization of the United Nations, and national food and agricultural authorities.

Preliminary – Corrections Pending

How is the Hazard Observed/Monitored/Forecast?	Monitoring weather conditions around crops and temperature/humidity in storage facilities will identify when the conditions are favourable for mould growth. Mould samples should be collected, cultured and analysed. Surveillance monitoring of food for aflatoxins against metrics and numeric standards will provide warning that levels are rising.

Risk Management: The World Health Organization (WHO) in collaboration with the Food and Agriculture Organization of the United Nations (FAO), is responsible for assessing the risk to humans of mycotoxins, through contamination in food, and for recommending adequate protection. Risk assessments of mycotoxins in food done by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) are used by governments and by the Codex Alimentarius Commission to establish maximum levels in food or provide other risk management advice to control or prevent contamination. Codex standards are the international reference for national food supplies and for food trade, so that people everywhere can be confident that the food they buy meets the agreed standards for safety and quality, no matter where it was produced (FAO/WHO, no date).

The outcome of such health risk assessments can either be a maximum tolerable intake (exposure) level, or other guidance to indicate the level of health concern (such as the Margin of Exposure), including advice on risk management measures to prevent and control contamination, and on the analytical methods and monitoring and control activities. Tolerable daily intakes are used by governments and international risk managers, such as the Codex Alimentarius Commission, to establish maximum levels for mycotoxins in food. The maximum levels for mycotoxins in food are very low due to their severe toxicity (FAO/WHO, no date; JECFA, no date).

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Coordinating agency or organisation

World Health Organization, Food and Agriculture Organization of the United Nations

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0202 / CHEMICAL / Carcinogens

Asbestos

Definition

Asbestos is the term for a group of naturally occurring fibrous silicate minerals widely used historically in building materials and other products (WHO, 2018). All types of asbestos cause lung cancer, mesothelioma, cancer of the larynx and ovary, and asbestosis (fibrosis of the lungs) (WHO, 2018).

Reference

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Preliminary – Corrections Pending

Annotations

GHS Classification (UNECE, 2023)

Synonyms

Chrysotile (white asbestos) and crocidolite (blue asbestos).

Additional scientific description

Asbestos is a Category 1A Carcinogen. Asbestos is known to have carcinogenic potential for humans, based on human evidence. The International Labour Organisation provides safety cards for chrysotile (white asbestos) and crocidolite (blue asbestos) (ILO, no date).

Asbestos has current or historical commercial use due to its extraordinary tensile strength, poor heat conduction, and relative resistance to chemical attack. For these reasons, asbestos is used for insulation in buildings and as an ingredient in a number of products, such as roofing shingles, water supply lines, and fire blankets, as well as clutches and brake linings, gaskets, and pads for automobiles (WHO, 2018).

The main forms of asbestos are chrysotile (white asbestos) and crocidolite (blue asbestos). Other forms include amosite, anthophylite, tremolite and actinolite (WHO, 2018).

All forms of asbestos are carcinogenic to humans. Exposure to asbestos, including chrysotile, causes cancer of the lung, larynx, and ovaries, and also mesothelioma (a cancer of the pleural and peritoneal linings). Asbestos exposure is also responsible for other diseases such as asbestosis (fibrosis of the lungs), and plaques, thickening and effusion in the pleura (WHO, 2018).

Metrics and numeric limits

There is no Threshold Limit for asbestos as it is carcinogenic. It should be completely removed from use and sequestered in ways that prevent human exposure to asbestos.

According to the World Health Organization (WHO), globally, about 125 million people are currently exposed to asbestos at the workplace. In 2004, asbestos-related lung cancer, mesothelioma and asbestosis from occupational exposure resulted in 107,000 deaths and 1,523,000 Disability Adjusted Life Years (DALYs) (WHO, 2014). In addition, nearly 400 deaths have been attributed to non-occupational exposure to asbestos. The burden of asbestos-related diseases is still rising, even in countries that banned its

use in the early 1990s. Owing to the long latency periods attached to the diseases in question, stopping the use of asbestos now will only result in a decrease in the number of asbestos-related deaths after a number of decades (WHO, 2014).

The WHO air quality guidelines for Europe estimate likely lifetime exposure for asbestos based on typical environmental concentrations and the associated health risk factors such as mesothelioma and lung cancer (WHO, 2000:38).

Key relevant UN convention / multilateral treaty

Asbestos Convention, 1986 (ILO, 1962).

Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (Basel Convention, 1989). At the time of writing, there were 187 parties to the Basel Convention.

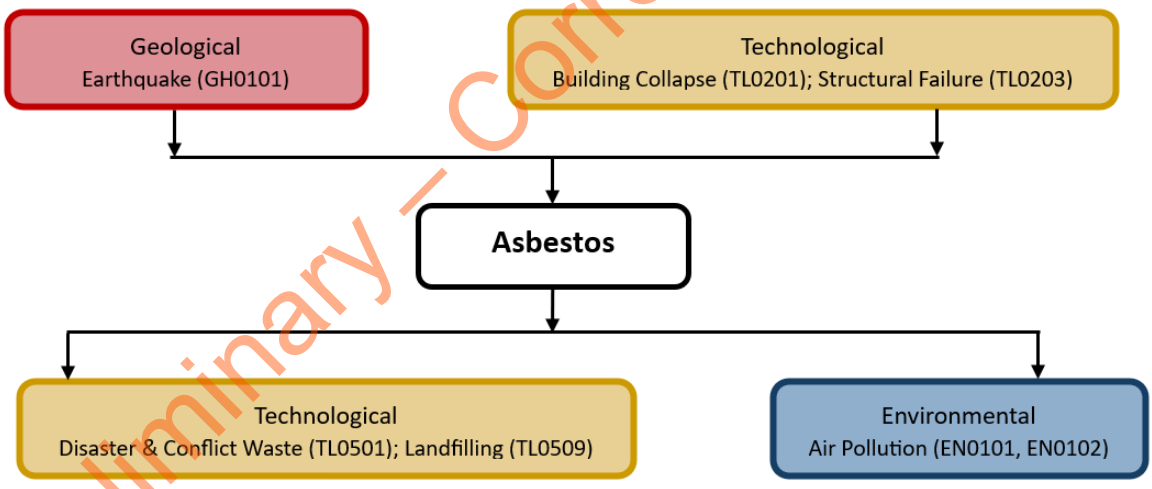
Examples of hazard drivers, impacts and risk management

Hazard drivers: In many disaster-prone areas, asbestos cement is widely used as a building material, and when the material corrodes due to aging or is damaged, it releases harmful asbestos fibres. Fires in buildings can release large amounts of dust and fibres from asbestos and fibreglass insulation (WHO, 2018).

The wide use of asbestos materials in construction means that any event that causes significant damage to buildings and other facilities has the potential to release asbestos dust and fibres (Whitmer, 2024). These represent a significant health hazard. Environmental events that affect opencast asbestos mines may also distribute asbestos dust and fibres.

Impacts: Asbestos is a proven human carcinogen (International Agency for Research on Cancer [IARC] Group 1). No safe level can be proposed for asbestos because a threshold is not known to exist. Exposure should therefore be kept as low as possible (IARC, 1987/1998).

Multi-hazard Context: The figure below summarises common interactions between asbestos and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Preliminary – Corrections Pending

Monitoring: The section and the table below offer an overview of monitoring asbestos. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	ILO, 1962. C162 - Asbestos Convention, 1986 (No. 162) IARC, 1987. Asbestos (Actinolite, amosite, anthophyllite, chrysotile, crocidolite, tremolite) WHO
How is the Hazard Observed/Monitored/Forecast?	As made clear under Drivers, above, asbestos release is often a result of other events that cause damage or fires in the vicinity of asbestos fibres (see Multi-Hazard Context). Early warning will therefore be related to those precipitating events, coupled with good risk management related to mapping areas with high asbestos burdens.

Risk Management: The WHO, in collaboration with the International Labour Organization and other intergovernmental organisations and civil society, works with countries towards the elimination of asbestos-related diseases by (WHO, 2014):

- Recognising that the most efficient way to eliminate asbestos-related diseases is to stop the use of all types of asbestos.
- Providing information about solutions for replacing asbestos with safer substitutes and developing economic and

technological mechanisms to stimulate its replacement.

- Taking measures to prevent exposure to asbestos in place and during asbestos removal (abatement).
- Improving early diagnosis, treatment, and rehabilitation services for asbestos-related diseases.
- Establishing registries of people with past and/or current exposures to asbestos and organising medical surveillance of exposed workers.
- Mapping of areas known to have high asbestos burdens may assist with disaster response.
- Providing information on the hazards associated with asbestos-containing materials and products, and by raising awareness that waste containing asbestos should be treated as hazardous waste.

Cost-effective interventions for preventing occupational lung diseases from exposure to asbestos are among the policy options for implementing the Global Action Plan for the Prevention and Control of Noncommunicable Diseases (2013-2020), as endorsed by the Sixty-sixth World Health Assembly in 2013 (WHO, 2013).

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Coordinating agency or organisation

World Health Organization (WHO), International Programme on Chemical Safety (IPCS)

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0203 / CHEMICAL / Carcinogens

Benzene and Hydrocarbons

Definition

Hydrocarbons are organic compounds composed entirely of hydrogen (H) and carbon (C) atoms. They are the simplest form of organic molecules and are the main components of fossil fuels such as coal, natural gas, and petroleum. Benzene is a clear, colourless, highly flammable and volatile liquid aromatic hydrocarbon (molecular formula C_6H_6) with a gasoline-like odour, which can lead to major public hazards. Benzene is the simplest aromatic hydrocarbon, characterised by alternating single and double bonds between the carbon atoms, forming a delocalized π-electron system. (WHO, 2019) The release of hydrocarbon ground gases, such as methane, can lead to major public hazards.

Reference

WHO, 2019. Preventing disease through healthy environments: Exposure to benzene: a major public health concern. World Health Organization (WHO). apps.who.int/iris/bitstream/handle/10665/329481/WHO-CED-PHE-EPE-19.4.2-eng.pdf?ua=1 Accessed 6 October 2024.

Preliminary – Corrections Pending

Annotations

GHS Classification (UNECE, 2023)

Synonyms

Paraffins; olefins; acetylenes; aromatic compounds; saturated hydrocarbons; unsaturated hydrocarbons; petrochemicals; benzol; phenyl hydride; cyclohexatriene; arene; coal naphtha.

Additional scientific description

Benzene (ICSC 0015, 2016) melts at 5.5°C and boils at 80.1°C; and has a high vapour pressure, which causes it to evaporate rapidly at room temperature, and is highly flammable. Methane and other light hydrocarbons exhibit similar properties. Benzene is slightly soluble in water but miscible with most other organic solvents (IPCS, 1993).

Benzene is used as a solvent in the chemical and pharmaceutical industries. It also occurs naturally in petroleum products (e.g., crude oil and gasoline) at levels up to 4 g/L. The primary route of benzene exposure and subsequent toxicity is via inhalation. The highest exposures have typically been in the workplace, for example, in industries that make or use benzene. The general population may be exposed through the inhalation of contaminated air, particularly in areas of heavy automobile traffic, gas stations and areas near industrial sources. Other sources include cigarette smoking, second-hand smoke, off-gassing from building

materials and structural fires. People also may be exposed to benzene in contaminated drinking-water and some foods (WHO, 2019).

The compulsory introduction of catalytic converters on car exhausts and legislation to reduce benzene levels in car fuels have contributed to a reduction of benzene emissions. Other interventions to prevent or reduce exposures to airborne benzene include promoting the use of alternative solvents in industrial processes, developing and implementing policies and legislation to remove benzene from consumer products, discouraging domestic use of benzene-containing products, promoting building codes requiring detached garages, and implementing the World Health Organization (WHO) Framework Convention on Tobacco Control (WHO, 2003), including providing for protection from exposure to tobacco smoke in workplaces and public areas.

Metrics and numeric limits

Drinking water: The WHO guideline value for benzene is 0.01 mg/L. This is based on extrapolation of modelled excess lifetime risk for leukaemia from epidemiological studies involving inhalation exposure; guideline values corresponding to modelled excess lifetime cancer risks of 10^{-4}, 10^{-5} and 10^{-6} are 0.1, 0.01 and 0.001 mg/L, respectively (WHO, 2019).

An excess lifetime cancer risk of 10^{-4}, 10^{-5} or 10^{-6} means the risk of one new cancer case above background levels per 10,000, 100,000 or 1 million people, respectively.

Air: No specific WHO guideline value has been developed for benzene in air. Benzene is carcinogenic to humans, and no safe level of exposure can be recommended. For general guidance, the concentrations of airborne benzene associated with an excess lifetime risk of leukaemia of 10-4, 10-5 and 10-6 are 17, 1.7 and 0.17 µg/m^3, respectively (WHO, 2019).

Benzene has a flash point: -11.1°C (12°F), making it highly flammable; a vapour pressure of 12.7 kPa at 25°C making it a volatile liquid. The Occupational Exposure Limit (OEL) for benzene is strictly regulated due to its toxicity and carcinogenicity (NIOSH, 2020; OSHA, 2024; EPA, 2024):

- OSHA Permissible Exposure Limit (PEL): 1 part per million (ppm) as an 8-hour time-weighted average (TWA).
- NIOSH Recommended Exposure Limit (REL): 0.1 ppm over a 10-hour workday.
- ACGIH Threshold Limit Value (TLV): 0.5 ppm TWA, with a short-term exposure limit (STEL) of 2.5 ppm.

Alkanes (Saturated Hydrocarbons)

- Methane (CH_4): Flash point: -188°C (-306°F); Explosive limits (LEL/UEL): 5% to 15% by volume in air.
- Hexane (C_6H_{14}): Flash point: -22°C (-7.6°F); Vapour pressure: 17.6 kPa at 20°C; Occupational exposure limit: OSHA PEL is 500 ppm (TWA).

Alkenes (Unsaturated Hydrocarbons)

- Ethylene (C_2H_4): Vapour pressure: 5.29 MPa (at 21°C); Occupational exposure limit: OSHA PEL for ethylene is 200 ppm (TWA).

Alkynes (Unsaturated Hydrocarbons)

- Acetylene (C_2H_2): Flash point: Extremely flammable, can ignite spontaneously under pressure in air; Explosive limits: 2.5% to 100% by volume in air.

Aromatic Hydrocarbons

- Toluene ($C_6H_5CH_3$): Flash point: 4.4°C (40°F); Vapour pressure: 3.79 kPa at 20°C; OSHA PEL: 200 ppm (TWA), NIOSH REL: 100 ppm (TWA), ACGIH TLV: 20 ppm (TWA).

Key relevant UN convention / multilateral treaty

International Labour Organization (ILO), The Benzene Convention, 1971 (ILO, 1971).

World Health Organization (WHO), The International Health Regulations 2005 (WHO, 2008).

European Union REACH Regulation: The Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) regulation in the European Union addresses the safe use of chemicals, including strong acids, and imposes requirements on their registration, evaluation, and authorization. (EUR-Lex, 2023)

United Nations Climate Change (UNCC), The Kyoto Protocol and Paris Agreement on Climate Change (UNCC, 2024).

United Nations Environment Programme (UNEP), Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (UNEP, 2011).

United Nations Environment Programme (UNEP), Rotterdam Convention on the Prior Informed Consent (PIC) Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (UNEP, 2010).

United Nations Environment Programme (UNEP), Stockholm Convention on Persistent Organic Pollutants (POPs) (UNEP, 2019).

Preliminary – Corrections Pending

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Benzene is a key building block in the production of various chemicals, including styrene, phenol, aniline, nylon, and rubber. Similarly, hydrocarbons such as methane, ethane, propane, and butane are crucial for energy production, heating, and chemical synthesis. Hydrocarbons like gasoline, diesel, and natural gas are primary energy sources for transportation, power generation, and industrial operations. Benzene and other hydrocarbons are used in paints, adhesives, detergents, and as solvents in industries such as pharmaceuticals and printing. Exposure is driven by leaks and spills from tanks and storage facilities.

As economies grow, particularly in emerging markets, the demand for energy, transportation fuels, and petrochemical products increases. Hydrocarbons play a critical role in meeting this demand. Expansion of urban centres and industries drives the demand for construction materials (plastics, polymers), energy for transportation, and heating fuels, leading to increased use of hydrocarbons and benzene derivatives.

Benzene and other hydrocarbons are economically attractive because they are cost-effective and have high energy content. Finding affordable, scalable, and safe alternatives to replace these substances in various industrial processes is challenging, prolonging their use.

Impacts: Acute occupational exposure to benzene may cause narcosis: headache, dizziness, drowsiness, confusion, tremors and loss of consciousness (consumption of alcohol enhances the toxic effect). It is also irritating to the eyes, skin and respiratory tract (WHO, 2019).

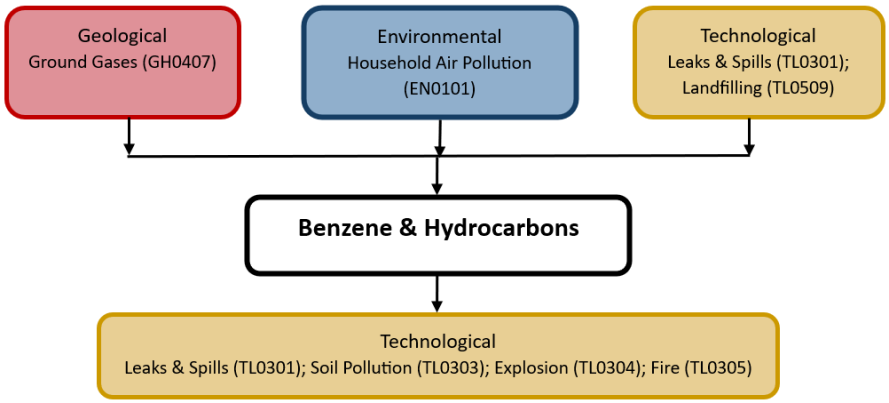
Benzene is a well-established cause of cancer in humans. The International Agency for Research on Cancer (IARC) has classified benzene as carcinogenic to humans (Group 1). The evidence in humans is considered sufficient for acute non-lymphocytic leukaemia, including acute myeloid leukaemia, while the evidence in humans is limited for non-Hodgkin lymphoma, chronic lymphoid leukaemia, multiple myeloma, chronic myeloid leukaemia, acute myeloid leukaemia in children, and lung cancer (WHO, 2019).

Oil spills are a huge concern and have major environmental and economic effects:

- **Short-Term Effects**: Immediate toxicity to marine organisms, smothering of wildlife, and destruction of habitats.
- **Long-Term Effects**: Persistent contamination of sediments and bioaccumulation of hydrocarbons in the food chain.
- **Economic Impacts**: Losses in fisheries, tourism, and clean-up costs, often amounting to billions of dollars.
- **Climate Interactions**: Oil spills exacerbate greenhouse gas emissions through methane release and contribute to global warming.

The largest oil spill occurred on 20th April 2010 on the Gulf of Mexico when the Deepwater Horizon drilling rig operated by BP exploded, killing 11 people and releasing approximately 134 million gallons of crude oil. This spill caused widespread damage to coral reefs and loss of marine biodiversity. Populations of fish, shrimp, and oysters declined sharply. Over 100,000 birds, dolphins, and other marine mammals died due to oil exposure and ingestion. Long-term effects include persistent contamination in marshes and seabed sediments, as well as mutations and reproductive issues in marine species like fish and crabs. (NOAA, 2020). There have been many other large oil spills throughout history, including the Exxon Valdez Oil Spill of 1989; the Amoco Cadiz Oil Spill of 1978; the Prestige Oil Spill of 2002; the Torrey Canyon Oil Spill of 1967; and many more. Preventing oil spills requires a combination of improved technology, strict regulation, effective monitoring, and stakeholder collaboration. Ongoing advancements in ship design, real-time monitoring systems, and offshore safety measures are essential to reducing the risk of spills and mitigating their impact when they occur.

Multi-hazard Context: The figure below summarises common interactions between benzene & hydrocarbons and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Preliminary – Corrections Pending

Monitoring: The section and the table below offer an overview of monitoring benzene & hydrocarbons. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Environmental agencies; industry regulatory bodies
How is the Hazard Observed/Monitored/ Forecast?	Air quality monitoring systems; leak detection systems; water, soil and marine monitoring systems

Risk Management: The WHO factsheet on Preventing disease through healthy environments - exposure to Benzene: a major public health concern (WHO, 2019) includes the following risk mitigation recommendations:

- Promote the use of alternative solvents in industrial processes, glues and paints.
- Develop and implement policies and legislation to remove benzene from consumer products.
- Reduce exposure at petrol filling stations as far as possible by following best practice in location, design and extraction.
- Regulatory compliance, advanced technologies, operational safety, and emergency preparedness are critical to ensuring safe and sustainable fuel transport.
- Minimise emissions from vehicle exhausts by improved design and regular monitoring of engine settings.
- Separate dwelling spaces from areas where vehicles and benzene-containing products are kept. In particular, isolate children from indoor exposure to vehicle emissions.
- Avoid domestic use of benzene-containing products.
- Discourage indoor use of unflued oil and gasoline heating.
- Implement the WHO Framework Convention on Tobacco Control (WHO, 2003), including providing for protection from exposure to tobacco smoke in indoor workplaces, public transport, indoor public places, and, as appropriate, other public places.
- Raise public awareness regarding sources of exposure to benzene, especially exposure through smoking, and awareness of risk mitigation measures.
- Conduct educational activities to discourage the use of benzene or petrol for cleaning and degreasing in industry, including in the informal sector.

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Coordinating agency or organisation

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0300 / CHEMICAL / Toxic Gases

Toxic Gases

Definition

Toxic gases are substances in the gaseous state that cause hazardous physiological effects when inhaled, affecting the respiratory, cardiovascular, and nervous systems, making them major public hazards (WHO 2000).

References

WHO, 2000. Air Quality Guidelines for Europe, Second Edition (2000). World Health Organisation (WHO). https://www.who.int/publications/i/item/9789289013581 Accessed 4 May 2024.

Preliminary – Corrections Pending

Annotations

GHS Classification (UNECE, 2023)

Synonyms

Poisonous gases; hazardous gases; noxious gases; toxic vapours; chemical fumes; pollutant gases.
(Cross Ref. HIP CH0400 Asphyxiant Gases)

Additional scientific description

Toxic gases work by complex mechanisms. Some toxic gases are naturally occurring, while others are produced as byproducts of industrial processes, combustion, or chemical reactions. Toxic gases include some that are naturally occurring ground gases released from magma in the ground, an example being radon. Polluted air is defined as air which contains gases and particles emitted to the atmosphere by a variety of human activities and natural sources or formed in the atmosphere. At critical levels, toxic gases have harmful effects on human health, animals, plants and ecosystems, or reduce visibility and corrode materials, buildings and cultural heritage sites (HIPs EN0101-EN0103). This polluted air is mainly composed of particulate matter, ground-level ozone (O_3) and nitrogen dioxide (NO_2).

Properties of toxic gases include their volatility, density and reactivity. Many toxic gases are highly volatile, meaning they can easily vaporise and spread through the air. Their density can affect their behaviour, for example, a gas heavier than air settles in low-lying areas, while lighter gases rise. Toxic gases can also be highly reactive and can form more harmful compounds when they interact with other substances or environmental elements. They can also be naturally occurring, or produced as byproducts of industrial processes, combustion, or chemical reactions. (ATSDR, 2024; EPA, 2024; NIOSH, 2020; WHO, 2000) The different classifications and examples include:

- Respiratory irritants: These gases destroy the mucosal barrier and produce inflammatory changes leading to a damaged

respiratory tract. Examples are ammonia (HIP CH0301; ICSC 0414), chlorine (HIP CH0303; ICSC 0126), formaldehyde (ICSC 0275), hydrogen sulphide (ICSC 0165), methyl bromide (ICSC 0109), methyl isocyanate (ICSC 0004), phosgene (ICSC 0007) and sulphur dioxide (ICSC 0074).

- Systemic/chemical asphyxiants: Inhaling these gases at high concentrations acts by displacing or excluding oxygen. They have specialised mechanisms, such as combining with haemoglobin or inhibiting cytochrome C oxidase, causing inhibition of cell oxygen utilisation resulting in histotoxic anoxia, which causes significant systemic toxicity. Examples are carbon monoxide (HIP CH0302; ICSC 0023), carbon disulfide (ICSC 0022) and hydrogen cyanide (ICSC 0494).
- Volatile compounds: Once absorbed, these compounds have little or no irritant effect; they act like anaesthetic agents, or they may exhibit toxicity towards the liver, kidneys, etc. Examples are anaesthetic gases; aliphatic, aromatic and halogenated hydrocarbon gases.

Metrics and numeric limits

Limits for air contaminants (OSHA, 2013; OSHA, 2017a, b; OSHA, 2021):

- Chlorine:1 ppm; 3 mg/m^3
- Hydrogen cyanide: 10 ppm; 11 mg/m^3
- Methyl bromide: 20 ppm; 80 mg/m^3
- Methyl isocyanate: 0.02 ppm; 0.05 mg/m^3
- Phosgene: 0.05 ppm
- Sulphur dioxide: 5 ppm; 13 mg/m^3

8-hour time weighted average:

- Formaldehyde: 0.5 ppm
- Phosphene: 0.3 ppm (0.4 mg/m^3)

Acceptable ceiling concentration:

- Hydrogen sulphide: 20 ppm

Key relevant UN convention / multilateral treaty

Organisation for the Prohibition of Chemical Weapons (OPCW), Chemical Weapons Convention (OPCW, 2024a,b).

United Nations Environment Programme (UNEP), Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (UNEP, 2011).

United Nations Environment Programme (UNEP), Rotterdam Convention on the Prior Informed Consent (PIC) Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (UNEP, 2010).

United Nations Environment Programme (UNEP), Stockholm Convention on Persistent Organic Pollutants (POPs) (UNEP, 2019).

World Health Organization (WHO), International Health Regulations (WHO, 2016).

World Health Organization (WHO), Environmental Health Criterion (WHO, 1981).

Examples of hazard drivers, impacts and risk management

Hazard Drivers: In industry, chemical manufacturing processes often use gases during production and can release gases such as carbon dioxide. The Dakar Ammonia Accident in 1992, where ammonia was used to detoxify the peanut oil product, involved a pressurised overfilled, poorly repaired ammonia tank which failed releasing 22 tonnes of ammonia. In this incident, there were 129 lives lost, with 1,150 other workers and citizens injured.

Another driver of toxic gases is their transportation, which can lead to accidental releases, particularly in the case of chemical spills or accidents involving tankers. Agricultural practices and waste management can also drive the release of toxic gases, such as ammonia and hydrogen sulphide from certain pesticides and fertilisers, and improper handling and disposal of hazardous wastes, leading to environmental contamination and human exposure. (EPA, 2024; NIOSH, 2020; WHO, 2000)

Some toxic gases are naturally occurring and can be released or created upon natural disasters, such as volcanic eruptions, wildfires, and certain geological formations. Examples of natural disasters include limnic eruptions, where dissolved carbon dioxide suddenly erupts from the deep waters of lakes. Carbon monoxide is also often released during power outages, including load shedding. (CDC, 2024)

Impacts of toxic gases include human health effects from inhalation; harm to ecosystems, soil quality, water quality and biodiversity, leading to long-term environmental degradation; economic losses due to cleanup and remediation efforts, healthcare expenses, property damage, and loss of productivity; and evacuations causing displacement of communities and social unrest. (EPA, 2024;

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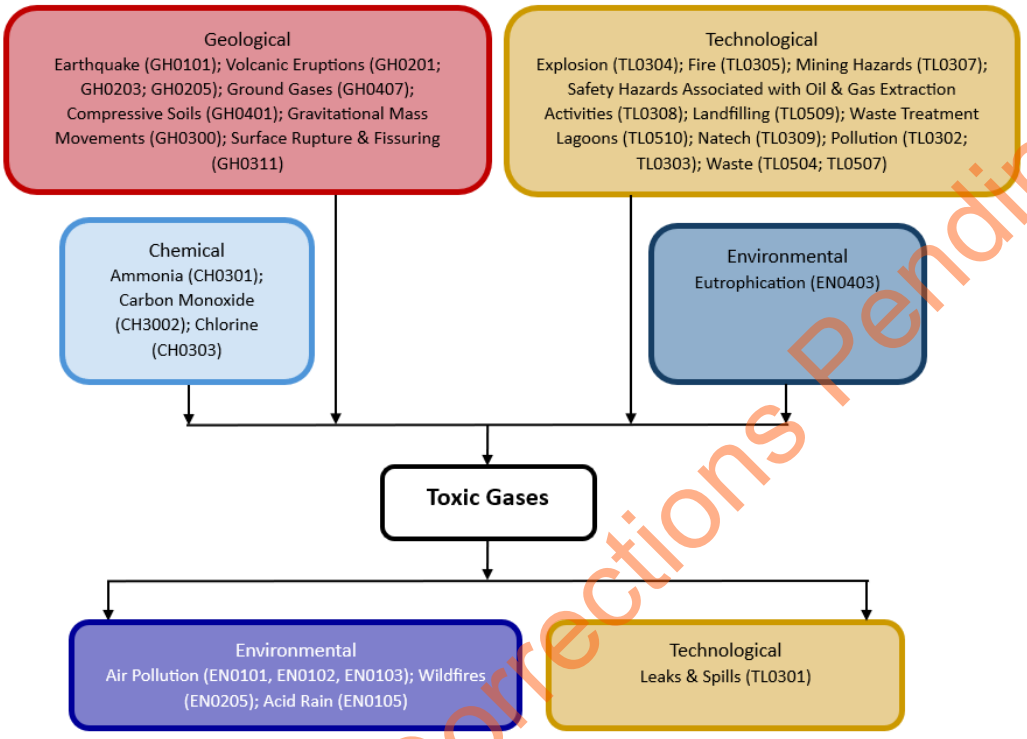
NIOSH, 2020; WHO, 2000)

Multi-hazard Context: The figure below summarises common interactions between toxic gases and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring toxic gases. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Depending on the source of the gases, national geological agencies, private compa management services
How is the Hazard Observed/Monitored/Forec	Detectors and sensors, communication systems, monitoring and control centres

Risk Management strategies include implementing engineering work to minimise toxic gas generation and release. Air quality monitoring systems and gas detection technologies can be used to detect and respond to toxic gas leaks or releases promptly. Also, developing emergency response plans, conducting drills, and providing training to personnel can mitigate impacts the of incidents. Reporting of emissions and releases is vital for adhering to regulatory requirements and standards. Educating the public about the risks and encouraging community engagement in pollution prevention efforts can minimise the risks associated of toxic gases. (EPA, 2024; NIOSH, 2020; WHO, 2000)

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Coordinating agency or organisation

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0301 / CHEMICAL / Toxic Gases

Ammonia

Definition

Ammonia (NH_3) is a colourless acrid-smelling reactive gas at ambient temperature and pressure and is considered a significant public health hazard (WHO, 1986; PHE, 2019).

References

WHO, 1986. Environmental Health Criteria 54: Ammonia. 10.4, Accidental exposure. International Programme on Chemical Safety, World Health Organization (WHO). www.inchem.org/documents/ehc/ehc/ehc54.htm#SectionNumber:10.4 Accessed 19 July 2024.

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Annotations

GHS Classification

Synonyms

NH_3, Anhydrous ammonia, Ammonia gas, Spirit of hartshorn, Azane.

Additional scientific description

Ammonia is a colourless, non-flammable gas, but is treated as flammable because it can form explosive mixtures with air. Ammonia dissolves readily in water. Solutions of ammonia are alkaline and can be corrosive when concentrated or mixed with water. In addition to irritation symptoms, delayed onset of serious respiratory symptoms may present, including corrosive damage to the mucous membranes of both the upper and lower respiratory tract (WHO, 1986; PHE, England 2019).

Ammonia is lighter than air, so the vapours from a leak will initially hug the ground. Long-term exposure to low concentrations or short-term exposure to high concentrations may result in adverse health conditions from inhalation. Prolonged exposure of containers to fire or heat may result in their violent rupturing and rocketing. Both liquid and vapours are extremely irritating, especially to the eyes (Cameo Chemicals, no date).

Ammonia is an extensively used industrial chemical. It is commonly used in the production of fertilisers, fibres and plastics, and explosives; as a cleaning and descaling agent, in food additives, and as industrial refrigerant (WHO, 1986).

High gaseous ammonia concentrations may be encountered locally, both in domestic and occupational environments, as a result of gaseous emissions and/or spillages of concentrated solutions. This can cause respiratory, skin or eye injury. On a larger scale, spillage from stock or transport tanks or refrigeration plants of

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concentrated ammonia liquor or anhydrous ammonia would constitute severe environmental damage and would cause serious injury to people, animals, and plants in the vicinity. Owing to its low density and short bio-persistence, major spillages would be expected to disperse rapidly and not to persist in the environment (WHO, 1990).

Ammonia can be stored and transported as a liquid at a pressure of 10 atm at 25°C. Ammonia dissolves readily in water where it forms, and is in equilibrium with ammonium ions (NH_4^+). The sum of ammonia and ammonium concentrations is termed 'total ammonia' and, owing to the slightly different relative molecular masses, may be expressed as 'total ammonia-nitrogen (NH_3-N)'. In most waters, NH_4^+ predominates, but increased pH or temperature or decreased ionic strength may materially increase levels of non-ionized ammonia (WHO, 1986).

Metrics and numeric limits

Drinking water: There is no health-based standard proposed by the World Health Organization (WHO) for ammonia in drinking water. This is because the odour threshold (1.5 mg/L) and taste threshold (35 mg/L) are considered to be below levels of health concern (WHO, 2011). However, ammonia has the potential to reduce the effectiveness of some water treatment techniques, and so some countries do prescribe a guideline value.

Air: There are no air quality guidelines for ambient levels of ammonia and public health. However, individual countries may develop occupational exposure limits and adopt acute/emergency guidelines.

On the other hand, guidelines do exist for ammonia and its health risks associated with larger releases of ammonia in accident scenarios. See for example: Emergency Response Planning Guidelines (ERPG) (NOAA, 2016) and Acute Exposure Guideline Levels for Airborne Chemicals (AEGLs) (US EPA, 2024).

Key relevant UN convention / multilateral treaty

United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (UNECE, 2024).

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Industrial refrigeration systems that use ammonia as a refrigerant can pose risks of ammonia leaks if not properly maintained or operated. Accidental releases of ammonia gas from refrigeration systems have led to evacuations, injuries, and fatalities in workplaces such as food processing facilities, cold storage warehouses, and ice rinks.

Ammonia is transported in bulk quantities by rail, tanker trucks, and pipelines for various industrial applications. Accidents involving derailments, collisions, or leaks during transportation or use can result in the release of ammonia gas into the environment. These incidents pose risks to nearby communities and emergency responders, who may be exposed to the toxic gas (US DOT, 2024).

Impacts: Breathing in low levels of ammonia may cause irritation to the eyes, nose and throat. High levels of ammonia may cause burns and swelling in the airways, lung damage and can be fatal. Ingestion of ammonia solutions can cause pain and burns throughout the digestive tract. In severe cases, the respiratory system, stomach and heart may be damaged, and death may follow. Strong ammonia solutions may cause serious burns if splashed on the skin. At high concentrations, gases and fumes of ammonia can also cause corrosive damage to the skin. Splashes in the eye may cause damage that may be irreversible in some cases and can lead to loss of sight. The health effects of ammonia are usually immediate, and long-term effects would not be expected after exposure to small amounts (PHE, 2019).

Anhydrous ammonia (liquid or gas) reacts with tissue water to form the corrosive solution ammonium hydroxide. Following body surface exposure, it is advised to disrobe, and improvised wet decontamination should be considered. Spillages and decontamination run-off should be prevented from entering watercourses (PHE, 2019).

Atmospheric ammonia can damage plant foliage when the rate of foliar uptake exceeds the rate at which the plant can detoxify ammonia. High levels of ammonia can affect plant growth and productivity, drought/frost tolerance, and plant response to insect pests and disease (Krupa 2003).

Multi-hazard Context: The figure below summarises common interactions between ammonia and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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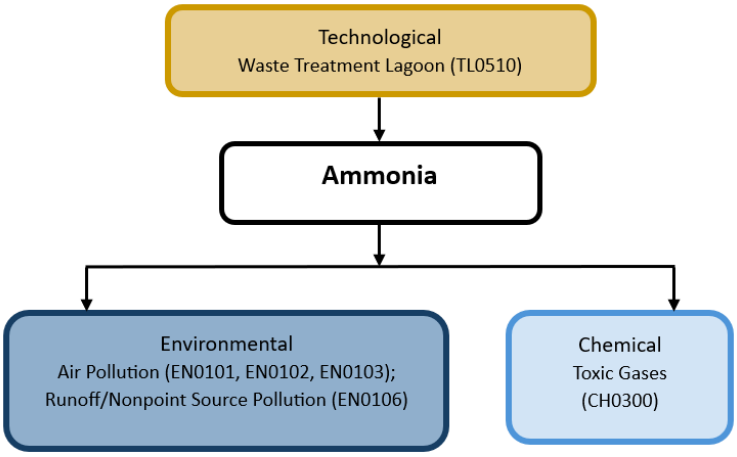

Monitoring: The section and the table below offer an overview of monitoring ammonia. This information can be do the same for this one, ISC style guide, give me a list only of things I need to change used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	World Health Organization (WHO) United Nations Environment Programme (UNEP) Environmental Protection Agency (EPA) Occupational Safety and Health Administration (OSHA).
How is the Hazard Observed/Monitored/Forecast?	Advanced monitoring sensors (both fixed and portable) to detect ammonia levels

Risk Management: Documented accidents underscore the importance of proper handling, storage, and transportation of ammonia, as well as emergency preparedness and response measures, to prevent and mitigate the impacts of ammonia-related incidents on public health and safety.

- Consider evacuation where spillage or leakage has occurred.
- Improvised wet decontamination should be considered in the case of skin contamination, as ammonia reacts with tissue water to form the corrosive solution ammonium hydroxide (PHE, 2019).
- Spillages and decontamination run-off should be prevented from entering watercourses (PHE, 2019) due to potential damage to plants and animals.
- Encourage the avoidance of agricultural land during the use of ammonia fertilisers (ATSDR, 2004).
- Harmonised labelling and transport approaches should be considered.

An early warning system for ammonia contamination is essential for promptly detecting and mitigating the risks associated with ammonia releases. These systems typically include advanced monitoring sensors (both fixed and portable) to detect ammonia levels in real-time. They employ technologies such as electrochemical and infrared sensors to provide accurate measurements. Data from these sensors is analysed and integrated into centralized systems that trigger audible, visual, and remote alerts when ammonia levels exceed safe thresholds. These alerts enable rapid response, ensuring the safety of personnel and minimizing environmental impact. By incorporating predefined response protocols, early warning systems for ammonia contamination help industries, agricultural operations, and wastewater treatment facilities prevent harmful exposure, comply with safety regulations, and protect public health and the environment.

- World Health Organization (WHO): Establishes health-based guidelines for ammonia exposure.
- United Nations Environment Programme (UNEP): Supports global initiatives for pollution monitoring and early warning systems.
- Environmental Protection Agency (EPA): Provides guidelines and regulations for ammonia monitoring and control. Supports the development of early warning systems through research and funding.
- Occupational Safety and Health Administration (OSHA). Sets permissible exposure limits (PELs) for ammonia in the workplace. Enforces regulations for ammonia monitoring and safety protocols.

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Coordinating agency or organisation

World Health Organization (WHO)

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0302 / CHEMICAL / Toxic Gases

Carbon Monoxide

Definition

Carbon monoxide is a colourless, odourless gas that can be poisonous to humans and is considered a significant public health hazard (WHO, 1999).

Reference

WHO, 1999. Environmental Health Criteria 213: Carbon monoxide. Second Edition. International Programme on Chemical Safety, World Health Organization (WHO). https://www.who.int/publications/i/item/9241540737 Accessed 11 May 2024.

Preliminary – Corrections Pending

Annotations

GHS Classification

Synonyms

CO, CO gas, Carbon monoxide gas, Carbonic oxide, Carbon (II) oxide, Flue gas (when referring to exhaust gases from combustion), Exhaust gas (specifically from engines and combustion processes)

Additional scientific description

Carbon monoxide (CO) is one of the most common and widely distributed air pollutants. It is a colourless, odourless and tasteless gas that is poorly soluble in water. Carbon monoxide has a slightly lower density than air. In the human body, it reacts readily with haemoglobin to form carboxyhaemoglobin. Small amounts of carbon monoxide are also produced endogenously. Carbon monoxide exposure is still one of the leading causes of unintentional and suicidal poisonings and causes a large number of deaths annually (WHO, 2000).

It is a product of the incomplete combustion of carbon-containing fuels and is also produced by natural processes or by biotransformation of halomethanes within the human body (Anders, 1985). With external exposure to additional carbon monoxide, subtle effects can begin to occur, and exposure to higher levels can result in serious symptoms and death. The health effects of carbon monoxide are largely the result of the formation of carboxyhaemoglobin (COHb), which impairs the oxygen-carrying capacity of the blood (WHO, 1999).

The total annual global emissions of carbon monoxide into the atmosphere have been estimated to be as high as 2600 million tonnes, of which about 60% are from human activities and about 40% from natural processes such as wildfires. Anthropogenic emissions of carbon monoxide originate mainly from the incomplete combustion of carbonaceous materials. The largest proportion of these emissions is produced as exhaust gases from internal combustion engines, especially by motor vehicles with petrol engines. Other common sources include various industrial processes, power plants using coal, and waste incinerators.

Petroleum-derived emissions have greatly increased over the past few decades. Some widespread natural non-biological and biological sources, such as plants, oceans and oxidation of hydrocarbons, give rise to the background concentrations outside urban areas. In indoor environments, space heaters fuelled with oil, gas or kerosene, gas stoves and some other combustion

appliances (e.g., wood stoves), and tobacco smoking are also responsible for significant emissions of carbon monoxide (WHO, 2000).

Metrics and numeric limits

Indoor air: 100 mg/m3 (87 ppm) for 15 minutes, 35 mg/m3 (30 ppm) for 1 hour, 10 mg/m3 (8.7 ppm) for 8 hours, 7 mg/m3 (6.1 ppm) for 24 hours (WHO, 2010).

Emergency response and acute exposure: Emergency Response Planning Guidelines (ERPG) (NOAA, 2016) and Acute Exposure Guideline Values for Airborne Chemicals (AEGLs) (US EPA, no date) exist for carbon monoxide.

Key relevant UN convention / multilateral treaty

United Nations Framework Convention on Climate Change (UNFCCC). Carbon monoxide, as a product of incomplete combustion, is relevant because its emissions are often associated with the burning of fossil fuels, which also produce carbon dioxide (CO2), a major greenhouse gas.

Stockholm Convention on Persistent Organic Pollutants (POPs). While carbon monoxide is not a persistent organic pollutant, the Stockholm Convention addresses the broader issue of air quality and the reduction of harmful chemicals released into the atmosphere.

Convention on Long-Range Transboundary Air Pollution (CLRTAP). This convention specifically aims to reduce and prevent air pollution, including carbon monoxide, which can travel long distances across borders.

World Health Organization (WHO) Air Quality Guidelines. The WHO provides global guidelines for air quality, including specific recommendations for acceptable levels of carbon monoxide exposure to protect human health.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers. Carbon monoxide is produced when fossil fuels burn without enough oxygen. The most important source of exposure to carbon monoxide for the general public is from cooking or other fuel-burning appliances which are poorly installed, faulty or used inappropriately (including inadequate ventilation).

Carbon monoxide can be related to: (1) Natural hazards: Example: Wildfires and forest fires can produce large amounts of carbon monoxide due to incomplete combustion of organic material. (2) Industrial Processes: Example: Industrial accidents, such as explosions or fires at manufacturing plants or refineries, can release significant quantities of carbon monoxide. (3) Urban Environments: Example: Heavy traffic and poorly ventilated urban areas can have high concentrations of carbon monoxide from vehicle exhaust. (4) Residential Heating and Cooking: Example: Improperly vented or malfunctioning heating systems and cooking appliances can produce dangerous levels of carbon monoxide indoors. (5) Climate Change: Example: Increased temperatures and altered weather patterns can influence the frequency and intensity of wildfires, thereby increasing carbon monoxide emissions.

Impacts. An example of the impacts of carbon monoxide contamination includes home boilers that are installed incorrectly, and the use of BBQs and portable generators inside homes, caravans and tents. Inhaling smoke from a house fire may lead to carbon monoxide exposure. For smokers, cigarettes are the major source of carbon monoxide. Use of shisha/hookah pipes may also lead to exposure. Exposure to low levels of carbon monoxide can occur outdoors, as it is produced by vehicle exhausts and industrial processes (PHE, 2019).

In emergency situations where power is lost, using an improperly vented generator inside a home or building, or using gas grills, charcoal grills, or hibachis indoors can lead to dangerous levels of carbon monoxide. Breathing high levels of carbon monoxide can be fatal. Breathing lower levels of carbon monoxide can permanently harm the heart and brain. Carbon monoxide tends to be more harmful to people with heart or lung disease (ATSDR, 2012). Similarly, the use of generators after meteorological and hydrological hazards such as gale, squall, storms and cyclones, can lead to dangerous levels of carbon monoxide.

Multi-hazard Context: The figure below summarises common interactions between carbon monoxide and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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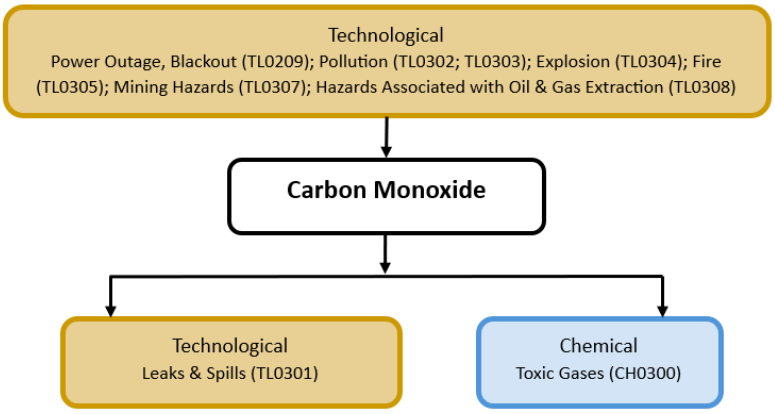

Monitoring: The section and the table below offer an overview of monitoring carbon monoxide. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disast Risk Data/Information?	World Health Organization (WHO)
How is the Hazard Observed/Monitored/Forecast?	Detection and monitoring technologies such as CO detectors, environmental surveillance from fixed and mobile monitoring stations, and public health notifications using alert systems.

Risk Management: Measures to limit impacts of carbon monoxide exposure include:

- Encourage means to reduce exposure in the home and indoor environment by discouraging the use of solid fuels, such as charcoal and biomass and encouraging cooking in well-ventilated spaces.
- Educate emergency services, volunteers and others to eliminate the use of generators in confined spaces where people may be exposed. This is particularly relevant during emergency and disaster response and recovery activities where main power supplies are lost.
- Public awareness campaigns contribute to the prevention of carbon monoxide poisoning in residential contexts.
- Consider regulating for safe installation of indoor heating appliances.
- Separate dwelling spaces from vehicle garages.
- Discourage the indoor running of combustion engine vehicles or require adequate ventilation where this is not possible.
- Avoid cigarette smoke and smoking (particularly pregnant women and children) as these are a source of carbon monoxide (and other hazardous chemicals).

Examples of early warning systems include detection and monitoring technologies such as CO detectors, environmental surveillance from fixed and mobile monitoring stations, and public health notifications using alert systems.

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Coordinating agency or organisation

World Health Organization (WHO).

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0303 / CHEMICAL / Toxic Gases

Chlorine

Definition

Chlorine is a reactive pale green gas with many uses, including disinfection of water. Chlorine is approximately 2.4 times heavier than air and has a characteristic odour similar to bleach. Most significant exposures to chlorine result from loss of containment of chlorine during storage and transport. Human exposure can result in symptoms ranging from mild irritation to rapid death related to pulmonary oedema. It is considered a significant public health hazard (adapted from IPCS, 1982 and PHE, 2019).

Preliminary – Corrections Pending

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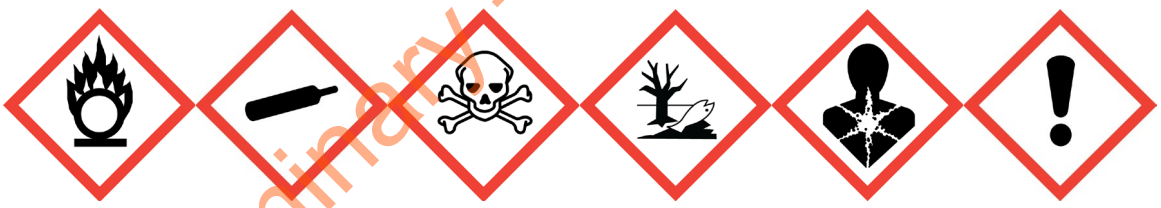
Annotations

GHS Classification (UNECE, 2023)



Synonyms

Cl_2, Chlor, Dichlorine, Bertholite, Molecular chlorine, Elemental chlorine, Chlorine gas, UN 1017 (for shipping and transport).

Additional scientific description

Chlorine (chemical symbol Cl, atomic number 17) reacts violently with bases and is a corrosive, strong oxidant. It also reacts violently with combustible substances and reducing agents and most organic and inorganic compounds, causing a fire and explosion hazard. It may also combine with water or steam to produce toxic and corrosive fumes of hydrochloric acid (PHE, 2019). During fires involving chlorine and carbon-containing materials, the formation of phosgene–a highly toxic pulmonary agent–may occur, representing an additional risk to emergency responders (Vaish, 2013).

Chlorine is used in the disinfection of water and in the production of bleach and chlorinated hydrocarbon solvents, polyvinyl chloride and other industrial processes. Large quantities are also used in the bleaching of pulp and paper.

Bleach contains sodium hypochlorite, which, if (inadvertently) mixed with acidic chemicals, can result in the generation and release of chlorine gas. If chlorine is released from a tank into the air, the chlorine will evaporate very quickly, forming a highly toxic greenish-yellow cloud (ATSDR, 2010). Due to its relatively low boiling point and high density compared to air, chlorine gas tends to settle in low-lying and enclosed areas, increasing the risk of accumulation and exposure in confined spaces.

Metrics and numeric limits

Drinking water: 5 mg/L (WHO, 2011).

Emergency response and acute exposure: there are Emergency Response Planning Guidelines (ERPG) (NOAA, 2016) and Acute Exposure Guideline Values for Airborne Chemicals (AEGLs) (US EPA, 2004) as a result of health risks associated with releases and spills of chlorine.

Key relevant UN convention / multilateral treaty

World Health Organization (WHO) International Health Regulations (WHO, 2016).

Organisation for the Prohibition of Chemical Weapons (OPCW), Chemical Weapons Convention. (OPCW, 2024a; b)

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Chlorine contamination is caused by anthropogenic activities that include accidents or misuse in industrial and similar settings, leading to significant health and environmental impacts.

Documented accidents involving chlorine, a highly reactive and toxic gas, have occurred in various industries and settings, leading to significant health and environmental impacts. Chlorine can be related to: (1) Industrial Accidents, (2) Natural hazards, (3) Urban Environments, (4) Terrorism and Sabotage, (5) Transport and Storage.

Chlorine Release Accidents in Chemical Plants:

Accidental releases of chlorine gas can occur in chemical manufacturing facilities, particularly those involved in the production of chlorinated chemicals such as PVC (polyvinyl chloride) and chlorine bleach. Chlorine gas is highly toxic and can cause respiratory irritation, lung damage, and even death at high concentrations (CDC, 2023 - https://emergency.cdc.gov/agent/chlorine/basics/facts.asp).

Chlorine is transported in railcars and tanker trucks for various industrial applications. Accidents involving derailments, collisions, or leaks during transportation can result in the release of chlorine gas into the environment. These incidents pose risks to nearby communities and emergency responders, who may be exposed to the toxic gas (USDT PHMSA, 2024, UK HSA, 2024).

Chlorine is commonly used in water treatment facilities to disinfect drinking water supplies. Accidental over-chlorination or equipment failures can lead to the release of excess chlorine into the water distribution system, resulting in elevated chlorine levels in drinking water and potential health risks for consumers. These documented accidents underscore the importance of proper handling, storage, and transportation of chlorine, as well as emergency preparedness and response measures, to prevent and mitigate the impacts of chlorine-related incidents on public health and safety.

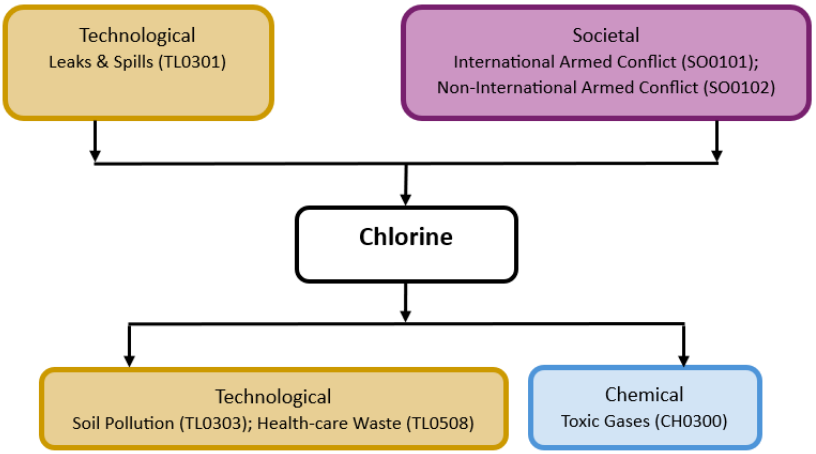
Impacts: Minor exposures to chlorine may result in a burning sensation of the eyes and throat. More substantial exposure may cause coughing or breathing difficulties. Exposure to high concentrations of chlorine gas can damage the lungs and airways, hours after the exposure, potentially without preceding warning symptoms; this may cause a build-up of fluid in the lungs (oedema), which can be fatal. Following severe injuries from inhaling chlorine, there may be shock, coma, and death, or when surviving, a chronic disorder of the lungs. Those exposed during physical exertion appear especially vulnerable (IPCS, 1982; PHE, 2019).

Owing to its hazardous nature, the majority of chlorine is transported by rail (ILO, 2004).

The modern use of chemical weapons began with World War I, when both sides in the conflict used poisonous gas to inflict agonising suffering and cause significant battlefield casualties. Such weapons basically consisted of well-known commercial chemicals put into standard munitions such as grenades and artillery shells. Chlorine was a common chemical used in this way historically and still presents a risk (United Nations Office for Disarmament Affairs, no date; OPCW, 2024a; b; c).

Multi-hazard Context: The figure below summarises common interactions between chlorine and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

Preliminary – Corrections Pending



Monitoring: The section and the table below offer an overview of monitoring chlorine. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster R Data/Information?	World Health Organization (WHO) Organization for the Prohibition of Chemical Weapons (OPCW), National terrc agencies
How is the Hazard Observed/Monitored/Forecast?	Sensors, monitoring networks; response protocols, portable gas detectors

Risk Management. Spillages and run-off should be prevented from entering watercourses as chlorine is harmful to the natural environment; evacuation should be considered in a written emergency plan for significant spills and leaks of chlorine such as from tanks; and harmonised labelling and transport approaches should be adhered to.

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Preliminary – Corrections Pending

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Coordinating agency or organisation

Organization for the Prohibition of Chemical Weapons (OPCW).

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0400 / CHEMICAL / Asphyxiant Gases

Asphyxiant Gases

Definition

Asphyxiant gases are gases that can cause unconsciousness or death by suffocation by displacing oxygen from the air. Asphyxiant gases that have no other health effects are considered simple asphyxiants. Simple asphyxiant gases become harmful to humans at high concentrations by lowering the percentage of oxygen in air (regularly present at 21%) to 19.5% or lower. (CCOHS, 2024)

Preliminary – Corrections Pending

References

OSHA Hazard Communication Standard (29 CFR 1910.1200) https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.1200

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Annotations

GHS Classification (UNECE, 2023)

Synonyms

Suffocant, Choking agent, Asphyxiating substance, Inert gas hazard, Oxygen-deficient atmosphere, Oxygen displacer, Smothering agent

Additional scientific description

Many asphyxiant gases are stored in and used from compressed gas cylinders or tanks. Large amounts, stored at high pressure, can displace air (and its oxygen) if it is released (accidentally or deliberately). (Cross Ref. GH0027 Ground Gases (CH4, Rn, etc.).

Examples of simple asphyxiant gases include:

(1) Nitrogen (N_2): Nitrogen is the most common gas in the Earth's atmosphere, comprising approximately 78% of the air we breathe. While nitrogen is not toxic, it can cause asphyxiation if present in high concentrations, displacing oxygen in the air.

(2) Helium (He): Helium is an inert gas that is lighter than air. It is commonly used in balloons, airships, and for various industrial purposes. While helium itself is not toxic, it can pose an asphyxiation risk if it displaces oxygen in confined spaces.

(3) Argon (Ar): Argon is another inert gas that is heavier than air. It is often used in welding and other industrial processes. Like nitrogen and helium, argon is not toxic, but it can cause suffocation by displacing oxygen in poorly ventilated areas.

(4) Carbon Dioxide (CO_2): While carbon dioxide is typically considered a simple asphyxiant at high concentrations, it also has toxic properties at elevated levels. CO_2 is produced by combustion processes, fermentation, and respiration. In confined spaces, high levels of carbon dioxide can displace oxygen, leading to asphyxiation.

(5) Low Molecular Weight Alkanes (LMWA): Low molecular weight alkanes refer to a group of saturated hydrocarbons such as methane, ethane, propane, and butane, that have relatively small numbers of carbon atoms. Several of these gases are denser than air, so they can accumulate in low-lying areas, posing asphyxiation hazards in confined spaces. They are also highly flammable gases at room temperature and pressure, and they can form explosive mixtures with air within specific concentration ranges. When handling LMWA, it is essential to observe several precautions to ensure safety and minimize risks associated with their flammability and air-displacing properties.

(6) Methane (CH_4): Methane is a colourless, odourless, highly flammable gas that belongs to the LMWA family. It is the primary component of natural gas. In addition to being a flammable hazard, methane can also act as a simple asphyxiant in confined spaces by displacing oxygen. As with the other LMWA compounds (see above), it can form explosive mixtures with air, particularly in confined spaces.

(7) Propane (C_3H_8): Propane is a colourless, odourless, highly flammable gas that belongs to the LMWA family. Propane is commonly used as a fuel where natural gas pipelines are not available, and thus it is widely known for its practical applications in residential, commercial, and industrial settings. It has a higher density than air and can accumulate in low areas. Adequate ventilation is crucial when using propane indoors to prevent the buildup of potentially dangerous concentrations.

Inhalation of these gases in high concentrations can cause symptoms of asphyxiation, including dizziness, confusion, rapid breathing, rapid heart rate, and loss of consciousness. It's important to ensure proper ventilation in areas where these gases are present and to use appropriate safety measures to prevent asphyxiation accidents.

Metrics and numeric limits (OSHA, 2013; OSHA, 2017a; b)

1. Nitrogen (N_2):
   - Permissible Exposure Limit (PEL): OSHA sets the PEL for nitrogen at 1,000,000 parts per million (ppm) as an 8-hour time-weighted average (TWA).
   - Threshold Limit Value (TLV): ACGIH recommends a TLV of 3,000,000 ppm as an 8-hour TWA for nitrogen.
   - Short-Term Exposure Limit (STEL): NIOSH suggests a STEL of 5,000,000 ppm for nitrogen over a 15-minute period.
2. Helium (He):
   - Permissible Exposure Limit (PEL): OSHA does not currently have a specific PEL for helium due to its inert nature and low toxicity.
3. Carbon Dioxide (CO_2):
   - Permissible Exposure Limit (PEL): OSHA sets the PEL for carbon dioxide at 5,000 ppm as an 8-hour TWA.
   - Threshold Limit Value (TLV): ACGIH recommends a TLV of 5,000 ppm as an 8-hour TWA for carbon dioxide.
   - Short-Term Exposure Limit (STEL): ACGIH suggests a STEL of 15,000 ppm for carbon dioxide over a 15-minute period.
4. Argon (Ar):
   - Permissible Exposure Limit (PEL): OSHA does not currently have a specific PEL for argon due to its inert nature and low toxicity.
5. Methane (CH_4):
   - Permissible Exposure Limit (PEL): OSHA sets the PEL for methane at 1,000 ppm as an 8-hour TWA.
   - Threshold Limit Value (TLV): ACGIH recommends a TLV of 1,000 ppm as an 8-hour TWA for methane.
   - Short-Term Exposure Limit (STEL): ACGIH suggests a STEL of 5,000 ppm for methane over a 15-minute period.
6. Propane (C_3H_8):
   - The immediate dangerous to life and health (IDLH) concentration for propane is 2,100 ppm (2.1% to 9.5% by volume). This is the concentration level from which one could escape within 30 minutes without experiencing any escape-impairing or irreversible health effects.

OSHA Hazard Information Bulletins, Potential Carbon Dioxide (CO_2) Asphyxiation Hazard When Filling, Stationary Low Pressure CO_2 Supply Systems. The current OSHA standard is 5000 ppm as an 8-hour time-weighted average (TWA) concentration.

Gaseous carbon dioxide is an asphyxiant. Concentrations of 10% (100,000 ppm) or more can produce unconsciousness or death (OSHA 1996).

Key relevant UN convention / multilateral treaty

1910.101 - Compressed gases (general requirements). Standard Number: 1910.101

Preliminary – Corrections Pending

Examples of hazard drivers, impacts and risk management

Hazard Drivers. Asphyxiant gases can be released into the environment through various natural and human activities. In addition to deliberate or accidental release from cylinders or tanks of compressed gases, some examples of drivers or sources of asphyxiant gases are:

- **Industrial Processes**: Many industrial processes involve the use or production of gases that can act as simple asphyxiants. For example:(a) Welding and metal fabrication can release argon or nitrogen used as shielding gases. (b) Chemical manufacturing processes may produce or release nitrogen, argon, or carbon dioxide. (c) Refineries and petrochemical plants can release methane and other gases during extraction, processing, and storage of hydrocarbons.
- **Agricultural Activities:** Agricultural practices can generate asphyxiant gases, particularly in confined spaces such as silos and manure pits. Decomposition processes in silage and manure can produce significant amounts of carbon dioxide and methane, which can displace oxygen.
- **Mining Operations:** Mining activities, particularly in underground mines, can generate asphyxiant gases due to natural processes and the use of machinery. Methane, carbon dioxide, and nitrogen can be present in mine atmospheres, posing risks to workers if not properly controlled.
- **Confined Spaces:** Any enclosed or poorly ventilated space has the potential to accumulate asphyxiant gases. This includes: Tanks, vessels, and storage containers where inert gases like nitrogen or argon may be used or present; underground tunnels, sewers, and manholes where natural gas or other gases may accumulate; Cargo holds of ships, where gases released from cargo or fuel may displace oxygen.
- **Natural Sources:** Some natural processes can also release asphyxiant gases into the environment: Volcanic eruptions can release large quantities of carbon dioxide, sulfur dioxide, and other gases; Decomposition of organic matter in stagnant water bodies, such as swamps or ponds, can produce methane and carbon dioxide; Geological processes, such as the release of gases from underground reservoirs or faults, can contribute to local concentrations of asphyxiant gases.
- **Accidental Releases:** Accidents involving storage, transportation, or handling of gases can lead to sudden releases of asphyxiant gases. For example, leaks from pipelines, storage tanks, or industrial equipment can result in the rapid buildup of gases in the surrounding area.

Impacts: The diverse range of activities and processes that can contribute to the presence of asphyxiant gases in the environment emphasizes the importance of proper monitoring, ventilation, and safety measures to prevent asphyxiation incidents. The impact of exposure to asphyxiant gases can range from mild symptoms of oxygen deprivation to severe injury or death, depending on the concentration of the gas, the duration of exposure, and individual susceptibility. Common outcomes of exposure to high concentrations of asphyxiant gases include:

- **Mild Symptoms**: Inhaling low to moderate levels of asphyxiant gases may initially cause mild symptoms such as dizziness, headache, confusion, shortness of breath, and rapid heart rate. These symptoms can escalate with prolonged exposure or higher concentrations of the gas.
- **Loss of Consciousness:** Continued exposure to high concentrations of asphyxiant gases can lead to loss of consciousness and unconsciousness due to oxygen deprivation. This can occur relatively quickly in poorly ventilated spaces or confined areas where the gas accumulates.
- **Suffocation and Asphyxiation:** Without intervention, prolonged exposure to high concentrations of asphyxiant gases can result in suffocation and asphyxiation, leading to permanent brain damage or death.
- **Explosions and Fires:** Some asphyxiant gases, such as methane, have flammable properties. In environments where oxygen levels are depleted due to the presence of the gas, there is an increased risk of explosions or fires if an ignition source is introduced.

Multi-hazard Context: The figure below summarises common interactions between asphyxiant gases and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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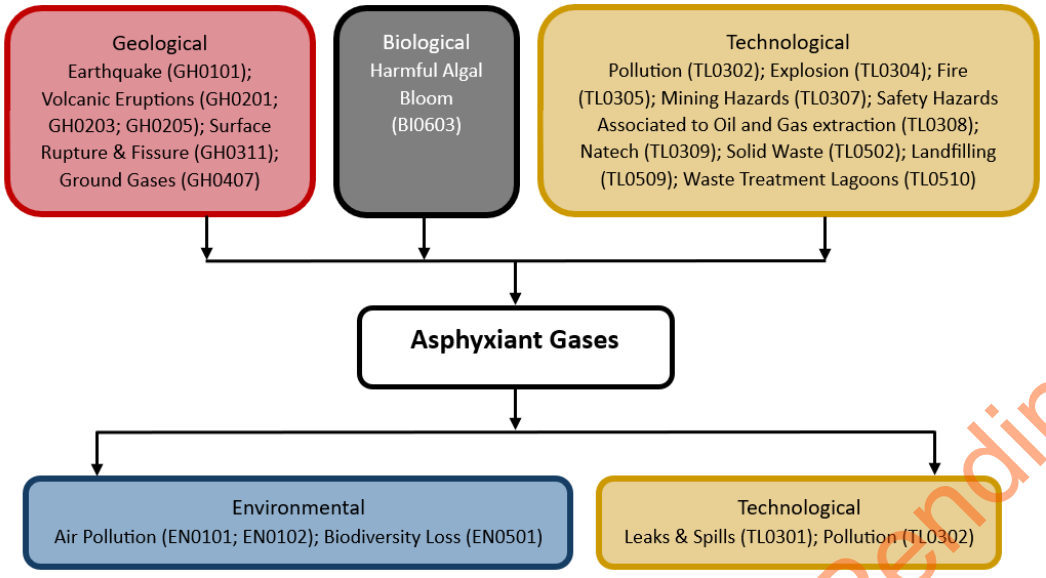

Monitoring: The section and the table below offer an overview of monitoring asphyxiant gases. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Ris Data/Information?	Depending on the source of the gases, national geological agencies, private compa fire management services
How is the Hazard Observed/Monitored/Fo	Oxygen sensors and similar devices for other gases, or multi-gas sensors, fitted wit appropriate alarms can detect and warn of developing asphyxiant circumstances

Risk Management strategies for dealing with asphyxiant gases aim to prevent exposure and mitigate the potential consequences. Here are some key risk management measures:

- **Hazard Assessment:** Identify sources of asphyxiant gases in the workplace through thorough hazard assessments and risk evaluations. Determine the potential for exposure and assess the risks to workers and the surrounding environment.
- **Engineering Controls:** Implement engineering controls to minimize the release and accumulation of asphyxiant gases. This may include proper ventilation systems, gas detection monitors, and inerting or purging procedures in confined spaces.
- **Administrative Controls:** Develop and implement administrative controls, such as safe work practices, procedures, and training programs, to minimize the risk of exposure to asphyxiant gases. Ensure that workers are aware of the hazards and know how to respond in case of an emergency.
- **Personal Protective Equipment (PPE):** Provide appropriate personal protective equipment, such as respiratory protection, for workers who may be exposed to asphyxiant gases. Ensure that PPE is properly fitted, maintained, and used according to manufacturer guidelines and regulatory requirements.
- **Emergency Response Planning:** Develop comprehensive emergency response plans and procedures for dealing with accidental releases of asphyxiant gases. Conduct regular drills and training exercises to ensure that workers are prepared to respond effectively in case of an emergency.
- **Monitoring and Testing:** Implement routine monitoring and testing programs to assess the concentration of asphyxiant gases in the workplace and ensure that exposure levels remain below regulatory limits. Use gas detection equipment to continuously monitor air quality in areas where asphyxiant gases may be present.

By implementing these risk management strategies, employers can effectively mitigate the hazards associated with exposure to asphyxiant gases and protect the health and safety of workers in the workplace.

References

Hazardous chemical means any chemical which is classified as a physical hazard or a health hazard, a simple asphyxiant, combustible dust, pyrophoric gas, or hazard not otherwise classified. https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.1200 Accessed 17 May 2024.

Simple asphyxiant means a substance or mixture that displaces oxygen in the ambient atmosphere, and can thus cause oxygen deprivation in those who are exposed, leading to unconsciousness and death.

The physical, health, simple asphyxiation, combustible dust, and pyrophoric gas hazards, as well as hazards not otherwise

Preliminary – Corrections Pending

classified, of the chemicals in the work area. OSHA Hazard Communication Standard (29 CFR 1910.1200).

International Organization for Standardization (ISO): ISO develops international standards on occupational health and safety management systems, risk assessment methodologies, and control measures. Relevant ISO standards include ISO 45001 (Occupational health and safety management systems) and ISO 31000 (Risk management).

Partain RA, Yiallourides C. Hydrate occurrence in Europe: Risks, rewards, and legal frameworks. Mar Policy. 2020 Nov;121:104122. doi: 10.1016/j.marpol.2020.104122. Epub 2020 Aug 16. PMID: 32836698; PMCID: PMC7428787.

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Coordinating agency or organisation

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0500 / CHEMICAL / Persistent Organic Pollutants (POPs)

Persistent Organic Pollutants

Definition

Persistent organic pollutants (POPs) are chemicals of global concern due to their potential for long-range transport, persistence in the environment, ability to bio-magnify and bio-accumulate in ecosystems, as well as their significant negative effects on human health and the environment.

References

WHO, 2020. Food safety: Persistent organic pollutants (POPs) World Health Organization (WHO). Food safety: Persistent organic pollutants (POPs) (who.int) Accessed 12 June 2024

Annotations

GHS Classification (UNECE, 2023)

Synonyms

Impurity, Contaminant, Pollutant

Additional scientific description

The most commonly encountered POPs are organochlorine pesticides, such as DDT, industrial chemicals, polychlorinated biphenyls (PCB) as well as unintentional by-products of many industrial processes, especially polychlorinated dibenzo-p-dioxins (PCDD) and dibenzofurans (PCDF), commonly known as dioxins.

Humans are exposed to these chemicals in a variety of ways: mainly through the food we eat (HIP CH0601), but also through the air we breathe, and through water, in the outdoors, indoors and at the workplace. Many products used in our daily lives may contain POPs, which have been added to improve product characteristics, such as flame retardants or surfactants. As a result, POPs can be found virtually everywhere on our planet in measurable concentrations.

POPs bio-magnify throughout the food chain and bio-accumulate in organisms. High concentrations of POPs are thus found in organisms at the top of the food chain. Consequently, trace levels of POPs can be found in the human body.

Human exposure - for some compounds and scenarios, even to low levels of POPs - can lead to many health effects, including increased cancer risk, reproductive disorders, alteration of the immune system, neurobehavioural impairment, endocrine disruption, genotoxicity and increased birth defects.

Preliminary – Corrections Pending

Dioxins (HIP CH0502) are one of the most common classes of POPs. Dioxins and dioxin-like substances are three or two-ring structures chlorinated to varying degrees. Dioxin is also used as the colloquial (short) name of the toxic by-product (and sometimes contaminant) of herbicides: 2,3,7,8-tetrachlorodibenzo[*b,e*][1,4]-dioxin (IUPAC 2014). Polychlorinated biphenyls (PCBs) can have up to 10 chlorine atoms substituting for hydrogen atoms, and polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) can have up to eight. The compounds tend to have similar toxicity profiles and common mechanisms of action and are generally considered together as a group to set guidelines (WHO, 2019).

PCDDs and PCDFs are widely present in the environment, occurring naturally, but mainly as unwanted by-products of combustion and of various industrial processes.2,3,7,8-tetrachlorodibenzo[*b,e*][1,4]-dioxin (TCDD) was a contaminant of a herbicide (2,4,5-T) and chlorodibenzofurans (CDFs) were major contaminants of PCBs, but neither PCDDs nor PCDFs have ever been manufactured or used for commercial purposes other than for scientific research. PCBs were globally manufactured and used in the past (WHO, 2019).

Although PCB manufacture is now prohibited under the Stockholm Convention, release into the environment still occurs from environmentally circulating POPs, the disposal of large-scale electrical equipment and waste from metallurgical uses, and from some chemical manufacture and processing (WHO, 2019).

Human exposure to dioxins and dioxin-like substances has been associated with a range of toxic effects, including chloracne; reproductive, developmental and neurodevelopmental effects; immunotoxicity; and effects on thyroid hormones, liver and tooth development. Dioxins are also carcinogenic. Developmental effects are the most sensitive human health endpoint, making children, particularly breastfed infants, a population at elevated risk (WHO, 2019).

Another common example of POPs organochlorine pesticides such as DDT (HIPs CH0501, CH0502). Half a million tonnes of obsolete pesticides are scattered throughout the developing world. These toxic chemicals, often stored outdoors in leaking containers, are seeping into the soil and water. Eliminating these dangerous stocks is a development priority. Rural communities cannot hope to develop if the soil and water are contaminated with pesticides. People cannot hope to prosper if they are suffering from severe illnesses caused by pesticide poisoning. The Food and Agriculture Organization of the United Nations (FAO) Programme on the Prevention and Disposal of Obsolete Pesticides is working to inform the world about the dangers of obsolete pesticide stocks. It collaborates with developing countries to prevent more obsolete pesticides from accumulating and assists them in disposing of their existing stockpiles (FAO, 1999).

POPs are found in many obsolete pesticides, including insecticides, fungicides, herbicides, larvicides, acaricides, rodenticides, molluscides, nematocides, and aphicides. Around a thousand active ingredients are used to manufacture the wide array of pesticides in countries all over the world. Pesticide ingredients come in many thousands of different formulations. All these formulations degrade over time, although some are more persistent in the environment than others. The chemical by-products that form as the pesticide deteriorates can be more toxic than the original product.

Once pesticides enter soil, their fate depends on the physicochemical characteristics of the soil, such as moisture, texture, and soil organic matter content, as well as the pesticide properties. A relatively small amount of spilled pesticides can therefore create a much larger volume of polluted soil. For example, approximately 30 tonnes of pesticides were buried at a site in Yemen in the 1980s, contaminating over 1500 tonnes of soil. This can pose a serious health and environmental threat to nearby communities (FAO, 2000)

Metrics and numeric limits

Toxic equivalency factors (TEFs) have been derived to relate the toxicities of individual PCDDs, PCDFs and PCBs to the most toxic of these compounds: TCDD, which is used as a reference and given a TEF of 1. The common mechanism of action for these substances means that their effects are additive, and TEFs for individual compounds can be used to establish the summed toxicity of a mixture. This approach has proved robust as a method for establishing the relative toxicities of these compounds (WHO, 2019), and has resulted in the development of guideline values as follows:

Provisional tolerable monthly intake: In 2002, the Joint Food and Agriculture Organization of the United Nations (FAO)/WHO Expert Committee on Food Additives (JECFA) established a provisional tolerable intake of 70 pg/kg body weight per month for PCDDs, PCDFs and coplanar PCBs expressed as TEFs.

Air: An air quality guideline for PCBs was not established because direct inhalation exposures constitute only a small proportion of the total exposure – in the order of 1-2% of the daily intake from food (WHO, 2019).

The TEFs were updated in 2022 (WHO, 2023; DeVito, 2024).

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Key relevant UN convention / multilateral treaty

The Stockholm Convention on Persistent Organic Pollutants was adopted by the Conference of Plenipotentiaries on 22 May 2001 in Stockholm, Sweden (UNEP, 2001). The Convention entered into force on 17 May 2004. By September 2019, 183 UN member states and the European Union had adopted the Stockholm Convention.

United Nations (2015) Sustainable Development Goals. Preventing soil pollution could reduce soil degradation, increase food security, contribute substantially to the adaptation and mitigation of climate change, and contribute to the avoidance of conflict and migration. Therefore, taking immediate actions to combat soil pollution contributes to the achievement of almost all Sustainable Development Goals (SDGs) (FAO, 2018).

The Food and Agriculture Organization of the United Nations (FAO) Programme on the Prevention and Disposal of Obsolete Pesticides is working to inform the world about the dangers of obsolete pesticide stocks. It collaborates with developing countries to prevent more obsolete pesticides from accumulating and assists them in disposing of their existing stockpiles (FAO, 2025)

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Agricultural Sector: The agricultural sector is a major source of POPs. Pesticides and herbicides used in farming contribute significantly to POPs contamination.

Manufacturing Industries: Secondary sources include manufacturing industries. Chemical production, especially older processes, can release POPs into the environment1.

Recycling and Thermal Processes: Recycling and thermal processes (such as waste incineration) can release POPs when handling materials containing these chemicals.

Improper Waste Disposal: Ill-planned waste disposal, including landfill sites, can lead to POPs contamination of soil and water.

Reservoirs: Reservoirs, such as large bodies of water, can accumulate POPs over time.

Impacts of POPs cause direct or indirect impacts on the environment due to interactions among biotic and abiotic elements. Their contamination disrupts ecological systems and threatens the environmental integrity and health of living organisms. The global production of these pesticides started to decline in the 1980s in response to increasing concerns about negative impacts on environmental and human health, mainly because POPs are resistant to degradation, bioaccumulate in food chains, and have adverse effects on ecosystems and human health.

The wide use of PCBs in electrical equipment. such as transformers. means that any events (weather, geological, technological) that damage electrical facilities may release such molecules. Industrial sites where PCDDs and PCDFs are produced (for example. as by-products) may be contaminated and need remediation. Accidents at chemical plants or during the transport of hazardous materials can result in the sudden release of POPs. Use of certain pesticides can introduce POPs into the environment, which can be further spread by natural and anthropogenic processes. Poorly managed landfills and improper disposal of electronic waste can lead to the leaching of POPs into soil and groundwater, leading to contamination of food and feed.

Multi-hazard Context: The figure below summarises common interactions between persistent organic pollutants and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify. or be otherwise related to each other. Specific examples of multi-hazard context can be found in the ‘Hazard drivers’ and ‘Impacts’ sections above.

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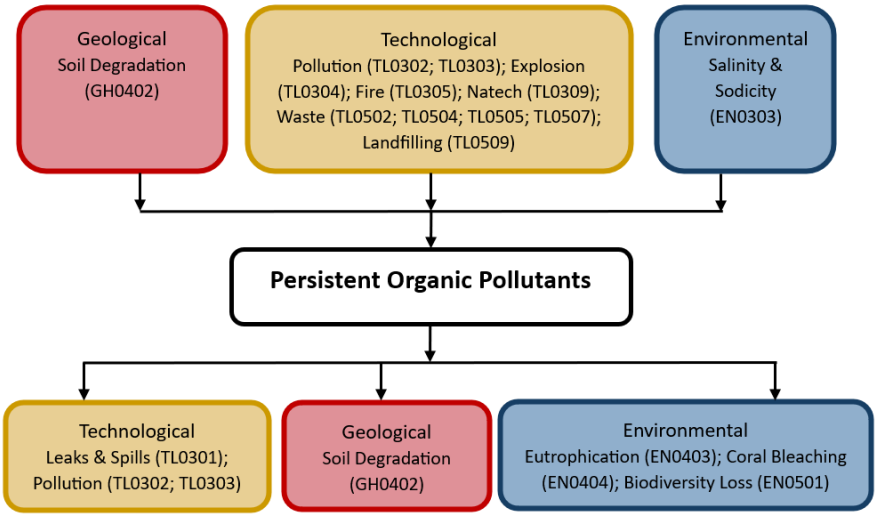

Monitoring: The section and the table below offer an overview of monitoring persistent organic pollutants. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	*Global Monitoring Plan (GMP) under the Stockholm Convention* Aims to provide a harmonized framework for monitoring the presence of POPs in the environment and human populations globally. *European Monitoring and Evaluation Programme (EMEP)* Focuses on monitoring air pollution, including POPs, across Europe to assess transboundary air pollution and support policymaking. *Integrated Atmospheric Deposition Network (IADN)* A U.S.-Canada initiative to monitor the deposition of toxic substances, including POPs, in the Great Lakes region.
How is the Hazard Observed/Monitored/Forecast?	The hazard posed by persistent organic pollutants (POPs) is monitored and forecasted through a combination of environmental sampling, predictive models, and real-time monitoring systems. Monitoring efforts are globally coordinated through organizations like UNEP, WHO, and national agencies, with data being shared internationally through frameworks such as the Stockholm Convention. These systems help assess current risks, forecast future trends, and issue early warnings in response to contamination events. The integration of meteorological, environmental, and health data plays a critical role in understanding and mitigating the long-term impact of POPs on both ecosystems and human health.

Risk Management: To address the risks associated with these substances, several steps have been taken to reduce or eliminate emissions of dioxins, dioxin-like PCBs and other related persistent organic pollutants. Many countries have now implemented the Stockholm Convention on POPs (2001), which suggests ending commercial use of 12 POPs and reduction or elimination of their emission into the environment. To monitor reduction in human exposure WHO and UNEP run a monitoring program for POPs in breastmilk. A steady decline in levels has been observed since 1980 for most countries.

In regard to food contamination, the FAO/WHO Codex Alimentarius Commission, which is a risk management body comprised of 169 member countries, is developing a draft code of practice for dioxins and dioxin-like PCBs in food, which identifies source-directed measures to reduce their presence in food, including fish, as well as a position paper, which provides an evaluation of the need for possible regulatory measures, such as limits in food and feed.

FAO and WHO consider fish to be an important component of a nutritious diet, and that the risk of consuming contaminated fish must be weighted in view of the beneficial nutritive effects of fish. FAO and WHO plan to develop general guidance for such risk-benefit considerations, with the contamination of fish as case studies. Dioxins and dioxin-like substances exposure occurs in the following ways (WHO, 2019):

- Associated with natural hazards: Dioxins can be generated by natural events, such as volcanic eruptions and forest fires.
- Industrial processes: PCDDs and PCDFs are by-products of industrial processes, particularly waste incineration, cement kilns firing hazardous waste, chlorine bleaching of pulp, and thermal processes in the

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metallurgical industry, as well as the manufacture of chlorophenols and phenoxy herbicides.

- Environmental media and food: Dioxin releases into air from inadequate incineration and releases into air, water or soil from industrial and waste sites contaminate soil and aquatic sediments, leading to bioaccumulation and bioconcentration through food chains. Most general population exposure is through ingestion of contaminated foods of animal origin.
- Waste disposal: Any source of organic materials in the presence of chlorine or other halogens will generate dioxins and furans during combustion. PCDDs and PCDFs are generated through the incineration of waste (domestic, industrial and health-care facilities) at low to moderate temperatures; guidance has been developed to identify and quantify releases from various incineration processes.

Actions to reduce emissions of these substances are required by the Stockholm Convention (UNEP, 2001). Interventions to reduce human exposure include: identifying and safely disposing of material containing or likely to generate dioxins and dioxin- like substances, such as electrical equipment; ensuring appropriate combustion practices to reduce emissions; implementing FAO/WHO strategies to reduce contamination in food and feed; and monitoring of food items, human breastmilk and air, as well as exposures in workers likely to be exposed to higher levels.

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Coordinating agency or organisation

International Union of Pure and Applied Chemistry (IUPAC)

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CH0501 / CHEMICAL / Persistent Organic Pollutants (POPs)

Pesticides

Definition

Pesticide means any substance, or mixture of substances of chemical or biological ingredients intended for repelling, destroying, or controlling any pest, or regulating plant growth.

Reference

UNEP, 2021. Highly Hazardous Pesticides (HHPs). www.unep.org/explore-topics/chemicals-waste/what-we-do/emerging-issues/highly-hazardous-pesticides-hhps Accessed 12 June 2024.

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Annotations

GHS Classification (UNECE, 2023)

Synonyms

Defoliant, Fungicide. Insecticide, DDT, Paraquat, Weedkiller, Nanopesticide

Additional scientific description

Pesticides can also be grouped according to the types of pests which they kill: insecticides (insects); herbicides (plants); rodenticides (rodents); bactericides (bacteria); fungicides (fungi); and larvicides (larvae) (WHO and FAO, 2016). Pesticides are used in many different sectors (e.g., agriculture, forestry, food industry, domestic, etc.).

Insecticides are chemicals used to control insects by killing them (CDC, 2019). Insecticides are classified based on their structure and function. They include:

a) Carbamates/Organophosphates: Humans may be exposed via inhalation, ingestion, or through skin contamination; and acute and chronic exposure can produce varying levels of toxicity. Similar to the insects exposed, these pesticides disrupt the function of the human nervous system, mainly the brain. They have also been linked to cancer risk. Their toxicity to humans has led to bans and use restrictions in many countries (CDC, 2019).

b) Organochlorines: These are a group of chlorinated compounds that typically affect the central nervous system. They are known for their high toxicity, slow degradation, and bioaccumulation. Examples include dichlorodiphenyltrichloroethane (DDT), methoxychlor, chlordane, and lindane. Human exposure may occur via inhalation, ingestion, or through skin contamination. Many organochlorines have been banned in many countries, although a few are still registered for use (CDC, 2019).

c) Boric acid: This type of pesticide comes in many forms (most commonly in pellets/tablets or a finely ground powder) and has many uses. It is a combination of boron and other elements. Toxicity depends on the amount of boron in the product. In addition to controlling insects, boric acid can be used to control the growth of moulds, fungi and weeds. Boric acid is low in toxicity but can still cause irritation to the skin or eyes, and nausea, vomiting, stomach aches and diarrhoea if ingested (CDC, 2019).

d) Pyrethroids/Pyrethrins: Pyrethrum is a naturally occurring mixture of chemicals found in certain chrysanthemum flowers. Pyrethrum was first recognised as having insecticidal properties around 1800 in Asia and was used to kill ticks and various

insects such as fleas and mosquitos. From pyrethrum extract, individual chemicals called pyrethrins, which have active insecticidal properties were developed. Pyrethroids are manufactured chemicals that are very similar in structure to the pyrethrins, but are often more toxic to insects, as well as to mammals, and last longer in the environment than pyrethrins (ATSDR, 2003). These insecticides are used widely in households, agriculture, on pets, and in mosquito control. While they are generally less toxic to mammals than some other insecticides, they can still have harmful health effects (CDC, 2019).

Fungicides are pesticides that kill or slow the growth of fungi and their spores. They can be used to control fungi that damage plants, including rusts, mildews and blights. They might also be used to control mould and mildew in other settings. Fungicides work in a variety of ways, but most of them damage fungal cell membranes or interfere with energy production within fungal cells (NPIC, 2019).

Pesticides are inherently toxic, and among them, a small number of Highly Hazardous Pesticides cause disproportionate harm to the environment and human health. Highly Hazardous Pesticides means pesticides that are acknowledged to present particularly high levels of acute or chronic hazards to health or environment according to internationally accepted classification systems such as WHO or the Global Harmonized System (GHS) or their listing in relevant binding international agreements or conventions. In addition, pesticides that appear to cause severe or irreversible harm to health or the environment under conditions of use in a country may be considered to be and treated as highly hazardous.

Around a thousand active ingredients are used to manufacture the wide array of pesticides in countries all over the world. Pesticide ingredients come in many thousands of different formulations, including nanopesticide formulations in which an active ingredient is carried on or within a nanoparticle. All these formulations degrade over time although some are more persistent in the environment than others. The chemical by-products that form as the pesticide deteriorates can be more toxic than the original product (FAO, no date b).

Hazardous pesticide contamination in soils often results from improper storage of (obsolete) agrochemicals, as a result of which pesticides are spilled in the surroundings of the storage site, where they seep into the soil or are dispersed by wind. In some cases, pesticide spillage has been ongoing for many years. Such spillage may cause serious soil or groundwater contamination. In addition, highly toxic and persistent compounds have been used in agriculture for decades to control pests and diseases, which are proven to cause harm to non-target species. Although international agreements have been put in place to regulate the production and use of those highly toxic and persistent compounds, they will still remain in soils for several more decades. Moreover, in some countries, the international agreements are not yet being implemented or fully implemented, and therefore toxic pesticides are still being used. When soil and groundwater are contaminated, crops, livestock and drinking water may become affected and, when they are consumed by people, health risks may occur (FAO, 2000).

Once pesticides enter soil, their fate depends on the physicochemical characteristics of the soil, such as moisture, texture, and soil organic matter content, as well as the pesticide properties. A relatively small amount of spilled pesticides can therefore create a much larger volume of polluted soil. For example, approximately 30 tonnes of pesticides buried at a site in Yemen in the 1980s contaminated over 1500 tonnes of soil. This can pose a serious health and environmental threat to nearby communities (FAO, no date c).

Pesticide residue refers to the pesticides that may remain on or in food after they are applied to food crops or owing to their persistence in the environment or because of other uses, such as vector control to combat endemic pests such as mosquitos transmitting malaria. Risk of pesticide residues mainly concerns the occupational health of field workers, food safety (consumer health) and the environment. The maximum allowable levels of pesticide residues in foods are often stipulated by national regulatory bodies and by the Joint Food and Agriculture Organization of the United Nations (FAO) / World Health Organization (WHO) Food Standards Programme (Codex Alimentarius Commission).

The following definitions are relevant to the Codex Alimentarius (FAO, no date):

Pesticide: means any substance intended for preventing, destroying, attracting, repelling, or controlling any pest, including unwanted species of plants or animals during the production, storage, transport, distribution and processing of food, agricultural commodities, or animal feeds, or which may be administered to animals for the control of ectoparasites. The term can also include substances intended for use as a plant growth regulator, defoliant, desiccant, fruit-thinning agent, or sprouting inhibitor and substances applied to crops either before or after harvest to protect the commodity from deterioration during storage and transport. The term normally excludes fertilisers, plant and animal nutrients, food additives, and animal drugs.

Metrics and numeric limits

Available data are too limited to estimate the overall global health impacts of pesticides; however, the global impact of self-poisoning (suicides) from preventable pesticide ingestion was estimated to be 155,488 deaths and 7362,493 Disability Adjusted Life Years (DALYs) for 2016 (WHO, 2019).

The WHO provides maximum residue limits (MRLs) for pesticides in food and levels in drinking-water as follows (WHO, 2019):

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- Maximum residue limits in food: The Joint Food and Agriculture Organization of the United Nations (FAO) / WHO Meeting on Pesticide Residues (JMPR) evaluates those pesticides likely to contaminate food. MRLs are published by the Codex Alimentarius Commission. Guidance for individual pesticides or pesticide components – including for a number of highly hazardous pesticides – can be accessed via the FAO, WHO, Codex Alimentarius Commission or National Framework for Chemicals Environmental Management (INCHEM) websites and in hard-copy publications.
- Drinking-water: WHO water quality guidelines exist for some pesticides used in agriculture and public health , including for some highly hazardous pesticides, where there is a likelihood of drinking-water contamination. Many pesticides have a maximum contaminant level given by the US Environmental Protection Agency of approximately 0.2 ppb (EPA, no date).

Key relevant UN convention / multilateral treaty

The Stockholm Convention on persistent organic pollutants (POPs) (UNEP, 2001). At the time of writing, there were 183 parties.

The Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Pesticides (1998). At the time of writing there were 161 parties.

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1989). At the time of writing, there were 187 parties.

The Montreal Protocol on Substances that Deplete the Ozone Layer (1987) has been ratified by all 197 UN Member States.

Examples of hazard drivers, impacts and risk management

Hazard Drivers of pesticide use include:

- Agricultural Productivity: The primary driver of pesticide use is the need to increase agricultural productivity. Pesticides help control pests and diseases that can significantly reduce crop yields.
- Economic Factors: The economic pressure to maximize crop yields and minimize losses drives farmers to use pesticides. The availability of cost-effective pesticides and their perceived benefits further incentivize their use.
- Technological Advancements: The development and commercialization of new pesticide formulations and delivery systems encourage their widespread use. Innovations in pest management techniques also play a role.
- Regulatory Policies: Government policies and subsidies can influence the use of pesticides. In some regions, subsidies for pesticide purchases promote their use, while regulations on permissible residues can limit it.
- Market Demands: Consumer preferences for aesthetically perfect produce lead farmers to use pesticides to ensure their crops meet market standards.

Impacts of exposure to highly hazardous pesticides include (WHO, 2019):

The use of pesticides in agriculture and other sectors intersects with multiple hazards, posing complex risks to health, environment, and economies. Pesticide exposure can cause immediate health effects such as skin rashes and respiratory issues, as well as long-term health effects including cancer, endocrine disruption and neurological disorders - vulnerable populations (such as children, pregnant women and agricultural workers) are particularly susceptible. The economic burden of health care for pesticide-related illnesses and the costs associated with environmental remediation can be substantial. Environmental hazards such as water contamination and soil degradation are caused by the leaching and accumulation of pesticides. Over-reliance on pesticides can lead to the development of resistant pest populations, necessitating the use of more or stronger chemicals, which increases costs for farmers. This could lead to a constant cycle of over-reliance leading to use of stronger pesticides leading to increased costs for health and environmental consequences. Pesticide residues on crops can affect market access, as international trade regulations and consumer preferences increasingly favour produce with low or no pesticide residues. (Aktar et al., 2009.; EEA, 2024; ILO, 2011). There is a possibility that excessive use of pesticides could reduce populations of insects required for plant pollination/reproduction, with consequent risks for food production.

Examples of impacts include:

- Unintentional and self-inflicted (suicide) acute poisonings by pesticides are a serious public health concern in many parts of the world.
- The acute hazard is highly variable depending on the pesticide and includes peripheral and central neurotoxicity and reduced blood clotting capacity. The specific pesticide formulation can significantly affect both exposure and toxicity. Short-term exposure can cause harmful effects on the liver, kidneys, blood, lungs, nervous system, immune system and gastrointestinal tract.
- Chronic exposure to highly hazardous pesticides can affect the skin, eyes, nervous system, cardiovascular system,

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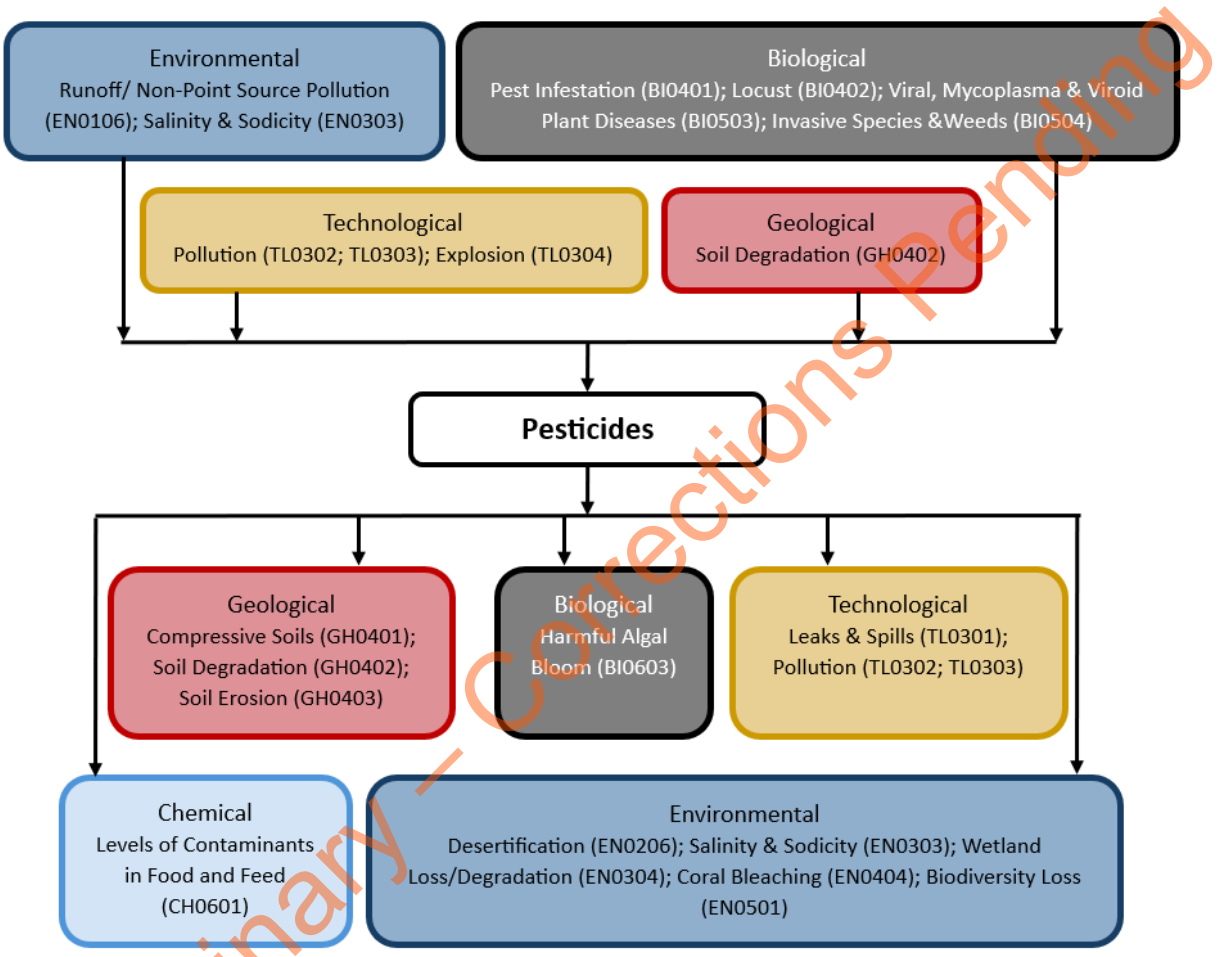
gastrointestinal tract, liver, kidneys, reproductive system, endocrine system, immune system and blood. Some highly hazardous pesticides may cause cancer, including childhood cancer.

- Toddlers and children are considered more vulnerable to exposure to pesticides due to their smaller size, hand-to-mouth activity, different metabolism, and because they are still developing.

Multi-Hazard Context: The figure below summarises common interactions between pesticides and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



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Monitoring: The section and the table below offer an overview of monitoring pesticides. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information	1. World Health Organization (WHO) WHO is a key institution for providing information on pesticide hazards from a health perspecti The organization offers reports and data on the toxicological effects of pesticides and related chemicals, as well as the risks of exposure during disasters, including natural hazards like floods storms. 2. Food and Agriculture Organization (FAO) FAO works on disaster risk reduction related to chemicals, providing training, guidelines, and information to countries on preventing pesticide misuse in disaster contexts. 5. European Food Safety Authority (EFSA) In Europe, EFSA is responsible for assessing the risks posed by pesticides to human health and t environment. 6. Environmental Protection Agencies (National Level) National environmental or agricultural agencies, like the U.S. Environmental Protection Agency (EPA) or India's Central Insecticides Board, may also monitor and report pesticide-related hazar especially during environmental disasters (e.g., floods, wildfires, chemical spills). 7. International Programme on Chemical Safety (IPCS)

	The IPCS, a joint initiative between WHO, UNEP, and the International Labour Organization (ILO conducts assessments of chemical hazards, including pesticides, and provides guidelines and da to reduce risks, especially during emergencies.
How is the Hazard Observed/Monitored/Forecast	Pesticide hazards are monitored and forecasted using a multi-disciplinary approach that combines environmental monitoring, meteorological forecasting, remote sensing, risk assessment models, a emergency response systems. These efforts help reduce the potential for harmful pesticide exposu particularly in the context of natural disasters, and support effective risk management strategies t protect public health and the environment.

Risk Management: Risk mitigation measures are critical. In 2015, the Strategic Approach to International Chemicals Management (SAICM) International Conference on Chemicals Management adopted a resolution that recognised highly hazardous pesticides as an issue of concern and called for concerted action by countries to address these substances, with emphasis on promoting agro-ecologically based alternatives and strengthening national regulatory capacity to conduct risk assessment and risk management (WHO, 2019). Several initiatives undertaken by international organisations, including the WHO/FAO, support this resolution. These include the publication of guidelines to support the International Code of Conduct on Pesticide Management, including those on highly hazardous pesticides, Good Labelling Practice for Pesticides, Pesticide Legislation and other important resources and guidance documentation to assist in the implementation of best practices, which have been brought together in a toolkit (FAO, 2018).

The highly hazardous pesticides risk reduction process consists of three main consecutive steps: identification of highly hazardous pesticides by checking registered pesticides against the FAO/WHO criteria; assessment of highly hazardous pesticides by assessing each product for risks and needs to determine whether action is desirable; and mitigation of highly hazardous pesticides risks by determining for each product whether risk mitigation measures are required, and if so, which options would be most appropriate (WHO, 2019).

To reduce exposure to highly hazardous pesticides and their health impacts, the WHO summarised actions required in the following areas: handling, storage, use and disposal; elimination and replacement of pesticide use; education; and regulation, monitoring and surveillance (WHO, 2019).

Early Warning Systems for pesticides are multi-faceted and require a combination of technological, regulatory, and community-based approaches to be effective.

Pesticide Action Network (PAN):

- PAN works globally to monitor and reduce pesticide risks through community-based action and policy advocacy.

European Union's Pesticide Monitoring Program:

- The EU conducts comprehensive monitoring of pesticide residues in food and the environment, informing policy decisions.

Integrated Pest Management (IPM) Programs:

- Many countries implement IPM programs that focus on reducing pesticide use through alternative pest control methods and monitoring.

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Coordinating agency or organisation

Food and Agriculture Organization of the United Nations (FAO), World Health Organization (WHO).

International Union of Pure and Applied Chemistry (IUPAC).

Preliminary – Corrections Pending

CH0502 / CHEMICAL / Persistent Organic Pollutants (POPs)

Dioxins and Dioxin-like Substances

Definition

Dioxins and dioxin-like substances, including polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are persistent organic pollutants (POPs, see CH0500) and are unwanted by-products of combustion and various industrial processes, such as the chlorine-bleaching of paper pulp and smelting. They can travel long distances from the source of emission, and bio-accumulate in food chains. These substances represent a major public health concern. They have been associated with a range of acute and long-term adverse health effects (WHO, 2019).

Reference

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Annotations

GHS Classification (UNECE, 2023)

Synonyms

Main classes: polychlorinated biphenyls (PCBs); polychlorinated dibenzo-p-dioxins (PCDDs); polychlorinated dibenzofurans (PCDFs)

Additional scientific description

Dioxins and dioxin-like substances' are three- or two-ring structures chlorinated to varying degrees. Dioxin is also used as a common name of the toxic by-product (and sometimes contaminant) of herbicides: 2,3,7,8-tetrachlorodibenzo[*b,e*][1,4]-dioxin (IUPAC 2014). Polychlorinated biphenyls (PCBs) can have up to 10 chlorine atoms substituting for hydrogen atoms, and polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) can have up to eight. The compounds tend to have similar toxicity profiles and common mechanisms of action and are generally considered together as a group to set guidelines (WHO, 2019). The International Labour Organisation provides a safety card for 2,3,7,8-tetrachlorodibenzo[*b,e*][1,4]-dioxin (ILO, no date).

PCDDs and PCDFs are widely present in the environment, occurring naturally, but mainly as unwanted by-products of combustion and of various industrial processes. 2,3,7,8-tetrachlorodibenzo[*b,e*][1,4]-dioxin (TCDD) was a contaminant of a herbicide (2,4,5-T) and chlorodibenzofurans (CDFs) were major contaminants of PCBs, but neither PCDDs nor PCDFs have ever been manufactured or used for commercial purposes other than for scientific research. PCBs were globally manufactured and used in the past (WHO, 2019).

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Although PCB manufacture is now prohibited under the Stockholm Convention, release into the environment still occurs from the disposal of large-scale electrical equipment and waste, from metallurgical uses, and from some chemical manufacture and processing (WHO, 2019).

Human exposure to dioxins and dioxin-like substances has been associated with a range of toxic effects, including chloracne; reproductive, developmental and neurodevelopmental effects; immunotoxicity; and effects on thyroid hormones, liver and tooth development. Dioxins are also carcinogenic. Developmental effects are the most sensitive human health endpoint, making children, particularly breastfed infants, a population at elevated risk (WHO, 2019).

Metrics and numeric limits

Toxic equivalency factors (TEFs) have been derived to relate the toxicities of individual PCDDs, PCDFs and PCBs to the most toxic of these compounds: TCDD, which is used as a reference and given a TEF of 1. The common mechanism of action for these substances means that their effects are additive, and TEFs for individual compounds can be used to establish the summed toxicity of a mixture. This approach has proved robust as a method for establishing the relative toxicities of these compounds (WHO, 2019), and has resulted in the development of guideline values as follows:

Provisional tolerable monthly intake: In 2002, the Joint Food and Agriculture Organization of the United Nations (FAO)/WHO Expert Committee on Food Additives (JECFA) established a provisional tolerable intake of 70 pg/kg body weight/month for PCDDs, PCDFs and coplanar PCBs expressed as TEFs. The TEFs were updated in 2022 (WHO, 2023; DeVito, 2024).

Drinking water: maximum contaminant level is given by the US Environmental Protection Agency as 0.00003 ppb (EPA, no date)

Air: An air quality guideline for PCBs was not established because direct inhalation exposures constitute only a small proportion of the total exposure – in the order of 1–2% of the daily intake from food (WHO, 2019).

Key relevant UN convention / multilateral treaty

The Stockholm Convention on Persistent Organic Pollutants was adopted by the Conference of Plenipotentiaries on 22 May 2001 in Stockholm, Sweden (UNEP, 2001). The Convention entered into force on 17 May 2004. By September 2019, 183 UN member states and the European Union had adopted the Stockholm Convention.

Examples of hazard drivers, impacts and risk management

Hazard Drivers Dioxins and dioxin-like substances exposure occurs in the following ways (WHO, 2019):

- Associated with natural hazards: Dioxins can be generated by natural events, such as volcanic eruptions and forest fires.
- Industrial processes: PCDDs and PCDFs are by-products of industrial processes, particularly waste incineration, cement kilns firing hazardous waste, chlorine bleaching of pulp, and thermal processes in the metallurgical industry, as well as the manufacture of chlorophenols and phenoxy herbicides.
- Environmental media and food: Dioxin releases into air from inadequate incineration and releases into air, water or soil from industrial and waste sites contaminate soil and aquatic sediments, leading to bio-accumulation and bioconcentration through food chains. Most general population exposure is through ingestion of contaminated foods of animal origin.
- Waste disposal: Any source of organic materials in the presence of chlorine or other halogens will generate dioxins and furans during combustion. PCDDs and PCDFs are generated through the incineration of waste (domestic, industrial and health-care facilities) at low to moderate temperatures; guidance has been developed to identify and quantify releases from various incineration processes.
- The wide use of PCBs in electrical equipment, such as transformers, means that any events (weather, geological, technological) that damage electrical facilities may release such molecules. Industrial sites where PCDDs and PCDFs are produced (for example, as by-products) may be contaminated and need remediation. Climate change and its effects may lead to wider dispersal of persistent organic pollutants (Teran 2012).

Impacts: Dioxins are carcinogenic and produce negative reproductive and developmental effects.

Multi-hazard Context: The figure below summarises common interactions between dioxins & dioxin-like substances and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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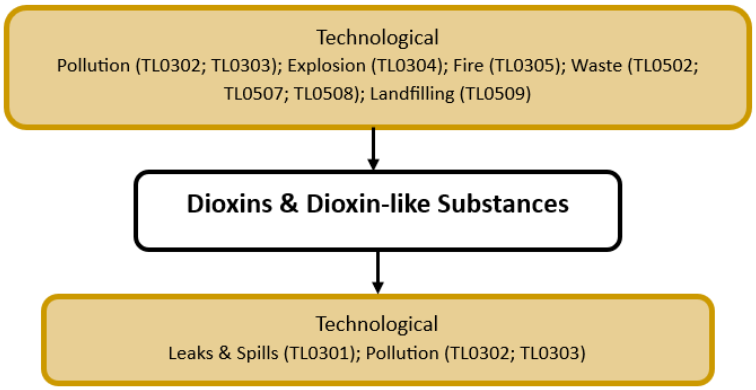

Monitoring: The section and the table below offer an overview of monitoring dioxins & dioxin-like substances. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster I Data/Information?	UNEP, 2001. Stockholm Convention on Persistent Organic Pollutants. WHO, 2023, WHO Fact Sheets Dioxins.
How is the Hazard Observed/Monitored/Forecast?	The Dioxin Monitoring Program - The EPA monitors dioxin levels in various media, including ai soil, and water, and conducts periodic National Dioxin Air Monitoring Network (NDAMN) assessments. (EPA, 2018) Japan's Dioxin Monitoring Network - Japan has established a comprehensive monitoring netw that includes regular sampling and analysis of dioxins in the environment and food supply, supported by rigorous regulatory standards. The Rapid Alert System for Food and Feed (RASFF) - as part of the food safety tools in Europe, RASFF was established to ensure the exchange of information between member countries to support swift reaction by food safety authorities in case of risks to public health resulting from food chain. (EC, 2024)

Risk Management: Actions to reduce emissions of these substances are required by the Stockholm Convention (UNEP, 2001). Interventions to reduce human exposure include: identifying and safely disposing of material containing or likely to generate dioxins and dioxin- like substances, such as electrical equipment; ensuring appropriate combustion practices to reduce emissions; implementing FAO/WHO strategies to reduce contamination in food and feed; and monitoring of food items, human breastmilk and air, as well as exposures in workers likely to be exposed to higher levels.

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Coordinating agency or organisation

Not identified.

Preliminary – Corrections Pending

CH0503 / CHEMICAL / Persistent Organic Pollutants (POPs)

Perfluoroalkyl and Polyfluoroalkyl Substances

Definition

Polyfluoroalkyl substances (PFAS) are a large family of chemicals in which multiple fluorine atoms are attached to an alkyl chain within a molecule. If all possible sites of an alkyl chain are occupied by fluorine atoms, the substance may also be referred to as a perfluoroalkyl substance as in perfluorooctanoic acid (PFOA) or perfluorooctanesulfonic acid (PFOS). (WHO, 2023).

Reference

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Preliminary – Corrections Pending

Annotations

GHS Classification (UNECE, 2023)

Synonyms

"Forever Chemicals", fluorinated compounds, Perfluorinated Compounds, Fluoropolymers, PFCs (Perfluorinated Chemicals), Fluoroalkyl Substances, Teflon Chemicals

Additional scientific description

PFAS are a large family of chemicals with a common feature: they contain carbon-fluorine bonds that make them highly stable, persistent, and resistant to degradation. They are widely used in various consumer products and industrial applications, but they also raise significant environmental and health concerns due to their persistence in the environment and their potential to accumulate in the human body. The European Union, The EU Commission, the U.S. Environmental Protection Agency (EPA), Centers for Disease Control and Prevention (CDC), and other health agencies have ongoing research and guidelines regarding the regulation, monitoring, and health risks associated with PFAS exposure. Because of their chemical structure, PFAS are also referred to as “forever chemicals” because they do not break down easily over time.

The most widely studied of these PFAS are perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA). Although the stability of PFOS and PFOA as well as their surfactant properties make them useful in consumer and industrial applications, there are concerns with their persistence and impacts on the environment and human health, as a result of exposure through the widespread uses of these chemicals. Drinking-water is one of several environmental sources of human exposure to PFAS, along with exposure via food, use in consumer products and occupational exposures (WHO, 2023)

Key Characteristics:

- Persistence: PFAS are extremely persistent in the environment and in human bodies due to the strong carbon-fluorine bond.
- Wide Application: PFAS are used in products such as stain-resistant fabrics, waterproofing agents, firefighting foams, and non-stick cookware.
- Health Concerns: Many PFAS chemicals have been linked to adverse health effects, including developmental effects, immune system disruption, liver toxicity, and cancer.

Metrics and numeric limits

PFAS (Per- and Polyfluoroalkyl Substances) are a large class of human-made chemicals, and various organizations, including the European Union, the EU Commission, the U.S. Environmental Protection Agency (EPA), World Health Organization (WHO), and other health and environmental regulatory bodies, have set guidelines and limits to manage exposure. These limits pertain to drinking-water quality, environmental contamination, food safety, waste management, and occupational exposure. Below are key metrics, numeric limits, and relevant guidelines.

On April 10, 2024, EPA announced the final National Drinking Water Standards for six PFAS (PFOS, PFOA, PFNA, PFBS, PFHxS, and GenX). The new limits require public water systems to monitor for PFAS at some of the lowest levels ever regulated. It also requires water systems to notify the public of PFAS levels in their drinking -water and take action if above the regulated values (US EPA, 2025).

In October 2022, the European Environment Agency (EEA) proposed quality standards for the sum of 24 PFAS, including PFOS, in surface water and groundwater. These were based on an opinion of the European Food Safety Authority (EFSA), supported by opinions of the Scientific Committee on Health, Environment and Emerging Risks. The proposed standard for surface and groundwaters is 4.4 ng/L (as PFOA equivalents) (EU, no date).

The key EU regulation for PFAS in drinking-water is the recast Drinking Water Directive (EU) 2020/2184, which came into force in January 2021 (EU, 2020).

WHO is still reviewing the available scientific evidence and has not yet established definitive guideline values for PFAS in drinking-water. The organization is continuing to assess the potential health risks associated with PFAS exposure through drinking-water and other sources.

Summary of Key Numeric Limits for PFAS in drinking-water:

Standard/Agency	PFAS Compound	Limit	Effective date
US EPA 2025	PFOA, PFOS	4.0 ppt (individually)	2029
US EPA 2025	PFHxS, PFNA, HFPO-DA (GenX)	10 ppt (individually)	2029
EU, no date	Sum of 20 PFAS	100 ng/L	2026
EU, no date	Total PFAS	500 ng/L	2026

Key relevant UN convention/multilateral treaty

PFAS are included in the Stockholm Convention. The Stockholm Convention on Persistent Organic Pollutants was adopted by the Conference of Plenipotentiaries on 22 May 2001 in Stockholm, Sweden (UNEP, 2001). The Convention entered into force on 17 May 2004. By September 2019, 183 UN member states and the European Union had adopted the Stockholm Convention.

Examples of hazard drivers, impacts and risk management

Hazard Drivers:

1. Widespread Industrial Use: PFAS chemicals have been used in a wide range of industries due to their water- and oil-repellent properties, chemical stability, and resistance to heat. This widespread use has led to their persistent presence in the environment.
2. Regulatory Gaps and Historical Use: PFAS were largely used before their full health and environmental risks were understood. In the past, chemicals like PFOA and PFOS were not well-regulated, and manufacturers did not initially recognize their long-term persistence;.
3. Environmental Persistence: PFAS are resistant to environmental degradation, leading to bioaccumulation in ecosystems. Once released into the environment, they can persist for decades or longer.

Impacts: PFAS are, in general, not an acute toxic substance to human health in the concentrations that normally surround humans. But given its effect on a long-term basis or in high doses due to e.g. accidents at chemical industry plants or industrial

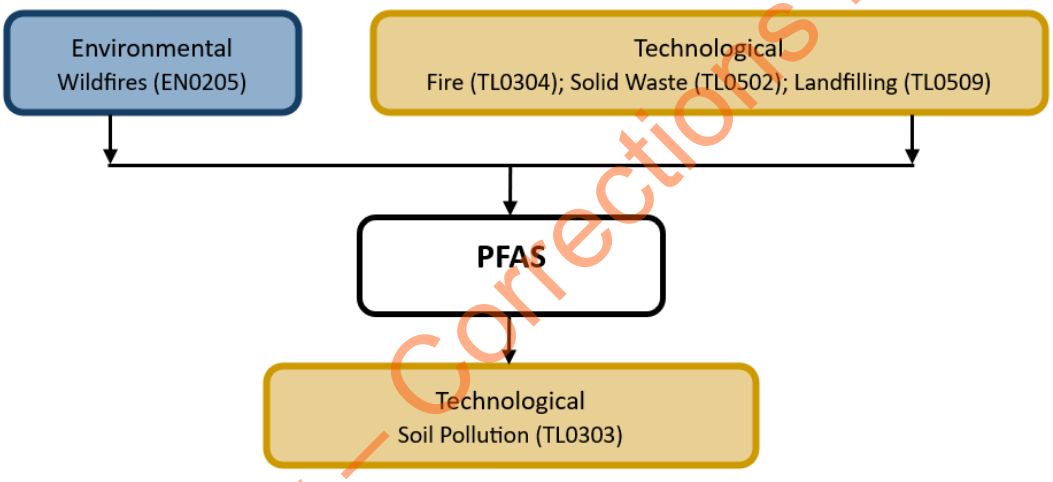
Preliminary – Corrections Pending

sites using PFAS in their production - such exposure could pose an increased risk to human health in a disaster situation. PFAS is so widespread - and is/has been used in many products - and it is found all over the world - including many inland water streams and rivers etc. - and in the sea - so when flooding occurs - due to heavy storms, increasing due to climatic change - PFAS contamination will follow. Therefore, monitoring is vital.

1. Health Impacts: PFAS are linked to a range of adverse health outcomes, including developmental, immune, liver, and kidney problems, and may be carcinogenic (EEA, 2023; IARC, 2025; CDC, no date).
2. Environmental Impacts: PFAS compounds can contaminate soil, water, and wildlife, leading to widespread environmental contamination that is difficult to remediate (EEA 2024).
3. Economic Impacts: The economic cost of PFAS contamination includes the cost of water treatment, cleanup of contaminated sites, and potential litigation.

Multi-hazard Context: The figure below summarises common interactions between PFAS and other hazards. Particular note should be made of fire as a multi-hazard context. Many fire-fighting foams contain PFAS, which raises the concern that response to one disaster situation could precipitate another (related to PFAS, in this case).

This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring PFAS. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster F Data/Information?	World Health Organisation (WHO) Environmental protection agencies
How is the Hazard Observed/Monitored/Forecast?	Environmental monitoring, advanced detection technologies, public h advisories, and regulatory frameworks

Risk Management:

1. Regulatory Actions: Governments around the world are increasing efforts to regulate PFAS and reduce exposure to these chemicals. The EU has set drinking water standards for PFAS, specifically PFOS + PFOA, limiting their presence to 0.1 µg/L (100 ng/L). The European Food Safety Authority has a significant programme of work related to PFAS (EFSA, 2024) Stockholm Convention. PFOS has been listed under the Stockholm Convention on Persistent Organic Pollutants (POPs), which regulates the production and use of certain persistent chemicals.
2. Technological Solutions for Remediation: Various technologies are being explored or used to address PFAS contamination, especially in drinking water and soil (EPA, no date).
3. Public Health and Awareness Campaigns: Increasing public awareness of PFAS risks is a key strategy in risk management (e.g. EWG, no date).

Early warning systems for PFAS contamination are critical for protecting public health and the environment. They rely on environmental monitoring, advanced detection technologies, public health advisories, and regulatory frameworks to identify contamination before it reaches dangerous levels. These systems also require collaboration across sectors and regions to

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address global contamination issues effectively. Key players such as the EPA, WHO, OECD, and regional governments are taking significant steps to build and enhance early warning systems to prevent and mitigate PFAS-related risks. Key Components of Early Warning Systems for PFAS are: 1. Environmental Monitoring; 2. Regulatory Surveillance and Health Impact Studies; Public Data Platforms and Transparency; 4. Early Detection Technologies; 5. International Collaboration

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Coordinating agency or organisation

World Health Organization (WHO); International Union of Pure and Applied Chemistry (IUPAC).

Preliminary – Corrections Pending

CH0504 / CHEMICAL / Persistent Organic Pollutants (POPs)

Microplastics

Definition

Microplastics are small plastic pieces less than five millimetres in length, which can be harmful to the environment, especially marine life. They originate from a variety of sources, including larger plastic debris that degrades into progressively smaller pieces (adapted from UNEP, 2016 and NOAA, 2023).

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Preliminary – Corrections Pending

Annotations

GHS Classification (UNECE, 2023)

Synonyms

Microparticles (IUPAC, 2012), Marine debris, microbeads, plastic particles.

Additional scientific description

Microplastics are routinely defined as small particles or fragments of plastic measuring less than 5 mm in length, which are insoluble in the aqueous environment. The broad classification of these small plastic residues is based on their size; (i) large microplastics of size ranging between 5 mm to 1 mm, (ii) small microplastics of 1 mm to 1 µm size range, and (iii) nanoplastics of <1 µm size. A more scientifically rigorous definition of plastic pieces might refer to nano, micro, meso, macro and mega-size ranges, although this has not yet been formally proposed for adoption by the international research community. At present, the lack of an agreed nomenclature, together with practical difficulties of sampling and measuring different size ranges in the field, has encouraged the widespread adoption of microplastics as a generic term for 'small' pieces of plastic.

There are primary and secondary sources of microplastics. The distinction is based on whether the particles were originally manufactured to be that size (primary) or whether they have resulted from the breakdown of larger items (secondary). Some microplastics are intentionally manufactured for industrial and domestic purposes ('primary'

microplastics). These include 'microbeads' used in cosmetic and personal healthcare products, such as toothpaste. 'Secondary' microplastics are created by the weathering and fragmentation of larger plastic objects. Weathering and fragmentation are enhanced by exposure to ultraviolet (UV) irradiation. These processes become extremely slow in the absence of UV radiation, as is the case in much of the ocean. Plastics marked as 'biodegradable' degrade more slowly in the ocean (UNEP, 2016). There is evidence that microplastics are littered into the environment at all steps in the life cycle of a plastic product, from producers to waste management. Microplastics can enter the marine environment via riverine systems, coastlines, directly at sea from vessels and platforms, or by wind-induced transport in the atmosphere. Methods of defining microplastics, sampling and measurement vary considerably among studies, source sectors and geographical regions, making it difficult to synthesize data across studies.

A special subclass of microplastics is nanoplastics. Nanoplastics are a form of marine debris, the significance of which is only now emerging. They are minuscule particles with dimensions of 1 to 100 nanometres (a nanometre is one millionth of a millimetre). It is important to note that nanoplastics do not have any legal definition, but the general definitions of nanomaterials can be adapted to nanoplastic particles. The most important definitions can be found in the standards ISO/TS 80004-1:2015, the regulation (EC) no 1223/2009 on cosmetic products, the regulation (EU) 2015/2283 on novel foods, and the regulation (EU) 1169/2011 on the provision of food information to consumers. Applying these definitions for polymer-based particles, it can be used as a definition for nanoplastics. It is very common for the two terms, nanoplastics and nanoparticles, to be used interchangeably in the literature.

A large proportion of the nanoplastic particles found in the ocean are of natural origin. It is the anthropogenic nanoplastics that are of concern. These originate from two sources: (i) nanoparticles created intentionally for use in industrial processes and cosmetics and (ii) from the breakdown of plastics in marine debris, from fragments of artificial fabrics discharged into urban wastewater, and through leaching from land-based waste sites (NOAA, 2021).

Recent scientific research has highlighted the potential environmental impacts of nanoplastics. For example, they appear to reduce primary production and the uptake of food by zooplankton and filter-feeders. Nanoparticles of titanium dioxide, which is widely used in paints and metal coatings and in cosmetics, are of particular concern. When nanoparticles of titanium dioxide are exposed to UV radiation from the sun, they transform into a disinfectant and have been shown to kill phytoplankton, which are the basis of primary production in the ocean. The scale of the threat from nanoparticles is unknown, and further research is required (UN, 2017).

About half the global population lives within 100 km of a coastline, and population growth is greatest in that zone. This means the amount of plastic debris entering the ocean from land-based sources is likely to increase unless significant changes are made to waste management practices on land (UNEP, no date).

Biodegradable plastics - Biodegradable polymers are able to undergo degradation into small molecules such as carbon dioxide (CO_2), methane (CH_4), and H_2O due to the action of biota, usually microorganisms, at a rate that is much faster than that for common plastics. The bio-prefix in bio-PE, bio-PET or bio-PA does not suggest that these polymers will therefore also be biodegradable. Some biopolymers, bio-derived plastics and bio-based plastics are indeed biodegradable. However, others in the same categories, such as the bio-based plastic bio-PE or the bio-derived plastic, fully acetylated cellulose, are not biodegradable.

Metrics and numeric limits

1. Environmental Metrics and Limits

Water Bodies: European Union (EU): The EU has proposed a threshold of 20 microplastic particles per litre of water for freshwater environments. This guideline is part of the broader Water Framework Directive aimed at maintaining the good ecological status of water bodies (European Commission, 2018)

United States Environmental Protection Agency (EPA): The EPA has yet to establish regulatory limits for microplastics in water, but they are actively researching the prevalence and impacts of microplastics (EPA, 2020).

Soil and Sediments: Research Studies: Studies have found varying concentrations of microplastics in soils and sediments. For instance, a study in agricultural soils found concentrations ranging from 78 to 593 microplastic particles per kilogram of dry soil (Piehl et al., 2018).

2. Human Health Metrics and Limits:

Drinking Water - The WHO has reviewed the presence of microplastics in drinking water and concluded that current evidence does not suggest significant health risks at present levels. However, they emphasize the need for further research (WHO, 2019).

Food Products - European Food Safety Authority has conducted risk assessments on microplastics in seafood, estimating that a European consumer might ingest up to 11,000 microplastic particles annually through seafood consumption (EFSA, 2016).

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3. Air Quality: Research Findings: Studies have found microplastics in indoor and outdoor air with varying concentrations. Indoor environments have been reported to have higher concentrations, ranging from 1 to 60 microplastic fibres per cubic meter (Dris et al., 2016).

4. Regulatory and Research Initiatives: United Nations Environment Programme (UNEP): UNEP is working on global guidelines and frameworks to address plastic pollution, including microplastics, with an emphasis on prevention and reduction strategies (UNEP, 2018).

Microplastic Research Projects: Various international projects are underway to understand the sources, distribution, and effects of microplastics. Notable examples include the "Microplastic Pollution" project by the National Oceanic and Atmospheric Administration (NOAA) and the European Marine Strategy Framework Directive.

Key relevant UN convention / multilateral treaty

The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972, the 'London Convention' for short, is one of the first global conventions to protect the marine environment from human activities and has been in force since 1975 (IMO, 1972). Its objective is to promote the effective control of all sources of marine pollution and to take all practicable steps to prevent pollution of the sea by dumping of wastes and other matter. Currently, 87 States are Parties to this Convention.

The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main international convention covering the prevention of pollution of the marine environment by ships from operational or accidental causes (IMO, 1996). The MARPOL Convention was adopted on 2 November 1973. The Protocol of 1978 was adopted in response to a spate of tanker accidents in 1976-1977. As the 1973 MARPOL Convention had not yet entered into force, the 1978 MARPOL Protocol absorbed the parent Convention. The combined instrument entered into force on 2 October 1983. In 1997, a Protocol was adopted to amend the Convention, and a new Annex VI was added, which entered into force on 19 May 2005. MARPOL has been updated by amendments over the years.

UN Member States endorsed a historic resolution to End Plastic Pollution and forge an international legally binding agreement by 2024. The resolution addresses the full lifecycle of plastic, including its production, design and disposal. The resolution, based on three initial draft resolutions from various nations, establishes an Intergovernmental Negotiating Committee (INC), which will begin its work in 2022, with the ambition of completing a draft global legally binding agreement by the end of 2024. It is expected to present a legally binding instrument, which would reflect diverse alternatives to address the full lifecycle of plastics, the design of reusable and recyclable products and materials, and the need for enhanced international collaboration to facilitate access to technology, capacity building and scientific and technical cooperation.

The BRS (Basel, Rotterdam, and Stockholm) Conventions are not specifically dedicated to plastic pollution, but they play a significant role in addressing various aspects of plastic waste management and chemical pollution. The Basel Convention is the most relevant of the three conventions for addressing plastic pollution: a) Plastic Waste Amendments: In 2019, the Conference of the Parties adopted amendments to include plastic waste in the scope of the Convention; b) Partnership on Plastic Waste (PWP): Established to improve and promote environmentally sound management of plastic waste and minimize its generation; c) Technical Guidelines: The Convention is updating guidelines for the identification and environmentally sound management of plastic wastes. The BRS Conventions are working together to address plastic pollution holistically, including its chemical components.

Examples of hazard drivers, impacts and risk management

Hazard Drivers *Primary Sources* - i) Personal Care Products: Microbeads in exfoliating scrubs, toothpaste, and cosmetics; ii) Industrial Applications: Microplastics used in sandblasting and as raw materials in manufacturing processes; iii) Agricultural Practices: Plastic mulching films and controlled-release fertilizers.

Secondary Sources - i) Plastic Waste Degradation: Larger plastic items breaking down into smaller particles through weathering, UV radiation, and mechanical action; ii) Synthetic Textiles: Microfibers released during the washing of synthetic fabrics like polyester and nylon; iii) Tire Wear: Tiny particles generated from the abrasion of tires on roads.

Environmental Dispersal Mechanisms - i) Atmospheric Transport: Microplastics can be carried by wind and atmospheric currents, depositing in remote areas; ii) Waterways: Rivers and streams transport microplastics from urban and rural areas to oceans; iii) Wastewater Treatment Plants: Effluent and sludge from treatment plants can contain and spread microplastics.

Given that humans can be exposed to microplastics through a variety of environmental media, including food and air, a better understanding of overall exposure to microplastics from the broader environment is needed (WHO, 2020).

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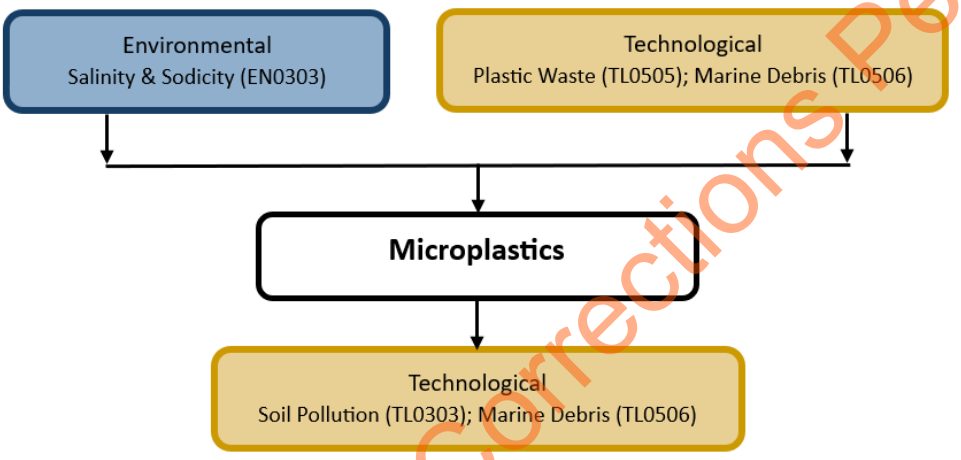
Impacts *Environmental Impacts - i) Marine* Ecosystems: Ingestion by marine organisms, leading to physical harm, digestive blockages, and chemical exposure; ii) Soil Health: Accumulation in agricultural soils, affecting soil structure and potentially entering the food chain through crops; iii) Freshwater Systems: Contamination of lakes and rivers, impacting freshwater species and ecosystems. *Human Health Impacts* - i) Ingestion: Consumption of microplastics through contaminated food and water, potentially leading to exposure to toxic chemicals; ii) Inhalation: Breathing in microplastic particles present in the air, particularly in urban environments; iii) Chemical Exposure: Microplastics can adsorb harmful pollutants, which can then enter the human body, posing risks such as endocrine disruption and carcinogenic effects. *Economic Impacts* - i) Fishing Industry: Decreased fish populations and contamination of seafood, affecting livelihoods and economies dependent on fishing; ii) Tourism: Pollution of beaches and water bodies can deter tourists, impacting local economies; iii) Waste Management Costs: Increased costs for cleaning up plastic pollution and managing waste effectively.

Multi-Hazard Context: The figure below summarises common interactions between microplastics and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Addressing the issue of microplastics in a multi-hazard context requires an integrated approach that considers the interactions between various environmental, anthropogenic, and socioeconomic factors. Effective management strategies must encompass regulatory measures, technological innovations, public engagement, and international cooperation to mitigate the impacts of microplastics on both the environment and human health. as demonstrated in the two cases below:

North Pacific Gyre (Great Pacific Garbage Patch)

Drivers: Ocean currents and human activity.

Impacts: Significant accumulation of microplastics affecting marine life and potentially entering the human food chain.

Risk Management: Initiatives like The Ocean Cleanup project aim to remove plastics from the ocean.

Urban Stormwater Management in Los Angeles

Drivers: Urban runoff and ineffective waste management.

Impacts: Microplastics are transported to the ocean, impacting marine ecosystems.

Risk Management: Implementation of green infrastructure and improved stormwater management practices to reduce runoff pollution.

Monitoring: The section and the table below offer an overview of monitoring microplastics. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	UNEP Global Monitoring Plan (GMP) – through its Global Monitoring Plan (GMP), collaborates with countries and organisations to monitor persistent pollutants, including microplastics, in air, water, and soil European Commission – Marine Strategy Framework Directive - OJ L 164, 25.6.2008, p. 19–40

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	The Ocean Cleanup – Plastic Pollution Index - PPI is a tool developed to map and predict plastic pollution, including microplastics, in marine environments The International Maritime Organization's (IMO) MARPOL Annex V
How is the Hazard Observed/Monitored/Forecast?	As made clear under Drivers, above, asbestos release is often a result of other events that cause damage or fires in the vicinity of asbestos fibres (see Multi-Hazard Context). Early warning will therefore be related to those precipitating events coupled with good risk management related to mapping areas with high asbestos burdens.

Risk Management The human health risk from microplastics in drinking water is a function of both hazard and exposure. Potential hazards associated with microplastics come in three forms: the particles themselves which present a physical hazard, chemicals (unbound monomers, additives, and sorbed chemicals from the environment), and microorganisms that may attach to and colonise microplastics, known as biofilms. Based on the limited evidence available, chemicals and microbial pathogens associated with microplastics in drinking water pose a low concern for human health. Although there is insufficient information to draw firm conclusions on the toxicity of nanoparticles, no reliable information suggests it is a concern (WHO, 2020).

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Coordinating agency or organization

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0601 / CHEMICAL / Chemical Hazards in Food and Pharmaceuticals

Levels of Contaminants in Food and Feed

Definition

A contaminant in food and feed is defined as any substance not intentionally added but present in such food or feed as a result of the production, manufacture, processing, preparation, treatment, packing, packaging, transport or storage, or as a result of environmental contamination, which can lead to major public hazards (FAO and WHO, 2019).

Reference

FAO and WHO, 2019. Codex Alimentarius Commission – Procedural Manual twenty-seventh edition. Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO). www.fao.org/3/ca2329en/CA2329EN.pdf Accessed 1 July 2024

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Annotations

GHS Classification (UNECE, 2023)

Synonyms

Maximum residue limits; acceptable daily intake; tolerable weekly intake; maximum levels; tolerance levels; permissible levels; contaminant limits.

Additional scientific description

Food contaminants include toxins and bacteria, but do not include insect fragments, rodent hairs and other extraneous matter. With an estimated 600 million cases of foodborne illnesses annually, unsafe food is a threat to human health, food security, nutrition and economies globally. Ensuring food safety is a public health priority and an essential step to achieving food and nutrition security. Effective national food safety and quality control systems are key not only to safeguarding the health and well-being of people, but also to fostering economic development and improving livelihoods by promoting access to domestic, regional and international markets (FAO/WHO, 2020).

Food poisoning is a form of contamination that can cause severe symptoms and illness, in some instances even becoming life-threatening. Common causes are harmful bacteria (*Bacillus cereus*, campylobacter, cronobacter, *E. coli*, listeria, salmonella, vibrio bacteria, yersinia) and viruses (Norovirus), with fungi, parasites, toxins (Clostridium botulinum) and natural contaminants being less common causes. Symptoms of foodborne illnesses include nausea or vomiting; diarrhoea; allergic reactions; headache; stomach cramps or pains; fever or chills; muscle or joint aches.

Metrics and numeric limits (EU, 2006; FAO/WHO, 2023; WHO, 2024)

Maximum Level: The maximum level for a contaminant in a food or feed commodity is the maximum concentration of that substance recommended by the Codex Alimentarius Commission to be legally permitted in that commodity. There are also national regulations for maximum levels.

Guideline Level: A guideline level is the maximum level of a substance in a food or feed commodity that is recommended by the Codex Alimentarius Commission to be acceptable for commodities moving in international trade. When the guideline level is exceeded, governments should decide whether and under what circumstances the food should be distributed within their territory or jurisdiction.

Note: A contaminant in food or feed is considered a risk for human health when above the maximum/guideline level established by the Codex Alimentarius Commission.

Common contaminants, including relevant Hazard Information Profiles and their limits:

1. Aflatoxins CH0201: EU: 2 µg/kg for aflatoxin B1 in nuts and dried fruits intended for direct human consumption; 4 µg/kg for total aflatoxins (B1, B2, G1, G2) in nuts and dried fruits.

   Codex Alimentarius: 10 µg/kg for total aflatoxins in peanuts intended for further processing; 15 µg/kg for total aflatoxins in other nuts intended for further processing.
2. Lead CH0103 (ICSC 0052, 2019): EU: 0.10 mg/kg in milk; 0.20 mg/kg in fruits and vegetables.

   Codex Alimentarius: 0.01 mg/kg in milk; 0.1 mg/kg in fruits and vegetables.
3. Mercury CH0104 (ICSC 0056, 2019): EU: 0.5 mg/kg in most fish; 1.0 mg/kg in predatory fish like swordfish and tuna.

   Codex Alimentarius: 0.5 mg/kg in most fish; 1.0 mg/kg in predatory fish.
4. Cadmium CH0102 (ICSC 0020, 2005): EU: 0.05 mg/kg in cereals; 0.2 mg/kg in leafy vegetables.

   Codex Alimentarius: 0.1 mg/kg in cereals; 0.2 mg/kg in leafy vegetables.
5. Pesticide Residues CH0501: EU: Varies by specific pesticide and food product (e.g., 0.01 mg/kg for chlorpyrifos in fruits).

   Codex Alimentarius: Varies by specific pesticide and food product (e.g., 0.01 mg/kg for chlorpyrifos in fruits).
6. Dioxins and PCBs (Polychlorinated Biphenyls) CH0502: EU: 1.75 pg/g for dioxins in meat and meat products; 3.5 pg/g for dioxins and dioxin-like PCBs in fish and fish products.

   Codex Alimentarius: Similar limits as the EU for comparable products.

Key relevant UN convention/multilateral treaty

Codex Alimentarius International Food Standards, Codex General Standard for Contaminants and Toxins in Food and Feed (CXS 193- 1995) (FAO/WHO, 2023).

Food and Agriculture Organization of the United Nations (FAO), Joint FAO/WHO Expert Committee on Food Additives (JEFCA) (FAO/WHO, 2024)

United Nations Environment Programme (UNEP), Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (UNEP, 2011).

United Nations Environment Programme (UNEP), Rotterdam Convention on the Prior Informed Consent (PIC) Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (UNEP, 2010).

United Nations Environment Programme (UNEP), Stockholm Convention on Persistent Organic Pollutants (POPs) (UNEP, 2019).

Examples of hazard drivers, impacts and risk management

Hazard Drivers include environmental sources such as contaminants from environmental pollution like heavy metals;,or from industrial activities and agricultural run-off containing pesticides and herbicides. Contaminants may also arise during food processing, packaging, or storage, due to inadequate hygiene practices, chemical additives, or unintentional contamination during manufacturing. Some contaminants are naturally occurring, such as mycotoxins, due to fungal growth under specific environmental conditions (HIP CH0201). (EEA, 2024; WHO, 2023)

Impacts include health risks, economic impact and regulatory compliance. Consumption of contaminated food and feed can lead to acute or chronic health effects, including cancer (e.g., from aflatoxins), neurological disorders (e.g. from heavy metals), and reproductive issues. Contamination incidents can result in economic losses due to recalls, market disruptions, and loss of consumer confidence in affected products and brands. Non-compliance with regulatory limits for contaminants can lead to legal consequences, trade restrictions, and sanctions affecting global market access for food and feed products. (CDC, 2024; EC, 2024)

Multi-hazard Context: The figure below summarises common interactions between levels of contaminants in food and feed and

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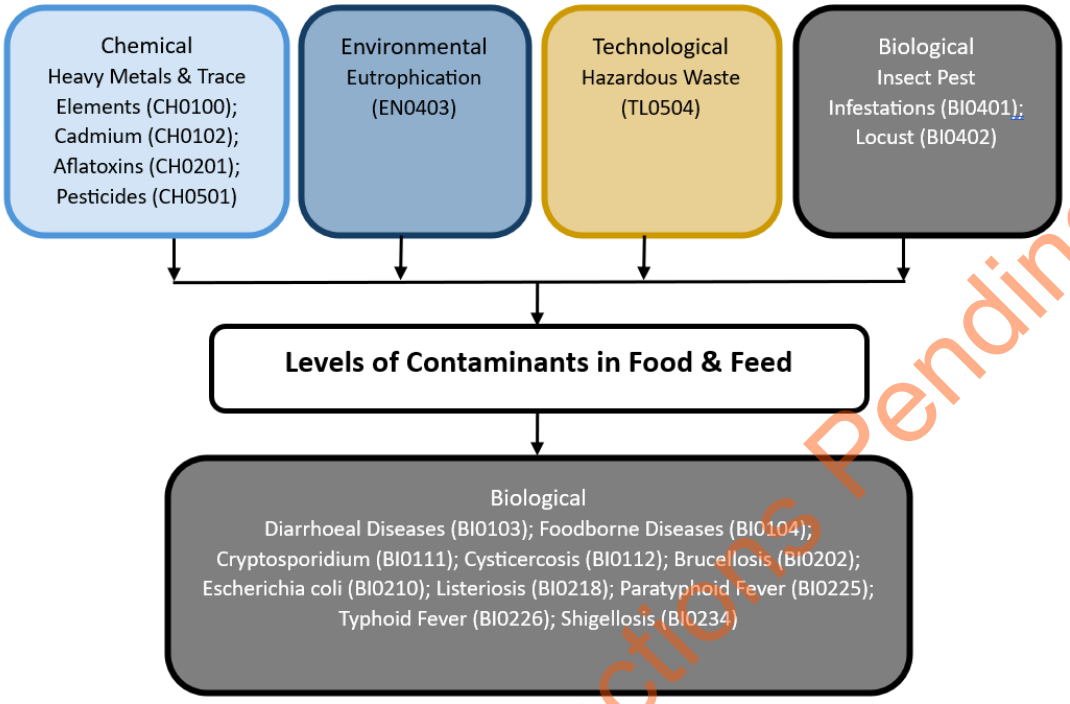
other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring levels of contaminants in food and feed. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Ri Data/Information?	Food and Agriculture Organization of the United Nations (FAO); World Health Organization (WHO); food and hygiene agencies
How is the Hazard Observed/Monitored/ Forecast?	Monitoring and testing at various stages of production, processing, distribution a consumption; data collection and analysis; risk assessments and rapid response.

Risk Management: National legislation and a food control system, including food import control, export control, and national monitoring programmes should be implemented. Establishing and monitoring Maximum Residue Limits (MRLs), Acceptable Daily Intakes (ADIs), and other regulatory standards to assess contaminant levels and potential risks. Implementing preventive controls at various stages of the food and feed production chain to minimise contamination risks, including sanitation practices and pest management. Good Agricultural Practices (GAP) should also be applied. (DEFRA, 2009) Developing and implementing rapid response plans for contamination incidents, including product recalls and communication strategies, are examples of corrective actions to mitigate public health risks.

Other measures of risk management include:

- Science-based harmonised texts such as Codex standards, recommendations, guidelines, codes of practice, analytical monitoring, national and international monitoring networks, warning of consumers, and retraction from the market.
- Normative work to support ensuring safe levels of contaminants in food and feed.
- Setting up Food Safety and Quality Programmes (FAO, 2014, FAO, 2024)
- FAO Risk Based Imported Food Control Manual (FAO, 2016)
- Safety risk management

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(UNEP). https://chm.pops.int/ Accessed 4 May 2024.

Coordinating agency or organisation

Joint Food and Agriculture Organization of the United Nations (FAO) / World Health Organization (WHO) Food Standards Program (Codex Alimentarius Commission) for the establishment of food safety standards i.e. MLs for contaminants (quantitative levels above which there is a risk to consumer's health).

Scientific inputs for ML standards setting are provided by the Food and Agriculture Organization of the United Nations (FAO) / World Health Organization (WHO) Expert Committee on Food Additives (JECFA).

International Union of Pure and Applied Chemistry (IUPAC)

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CH0602 / CHEMICAL / Chemical Hazards in Food and Pharmaceuticals

Substandard and Falsified Medical Products

Definition

Substandard and falsified medical products are defined as those that may cause harm to patients and fail to treat the diseases for which they were intended (WHO, 2018).

Reference

WHO, 2018. Substandard and falsified medical products. World Health Organization (WHO). www.who.int/news-room/fact-sheets/detail/substandard-and-falsified-medical-products Accessed 22 September 2024.

Annotations

GHS Classification (UNECE, 2023)

Synonyms

Counterfeit medicines, Fake medicines

Additional scientific description

Substandard and falsified medical products lead to loss of confidence in medicines, healthcare providers and health systems. They affect every region of the world. Substandard and falsified medical products from all the main therapeutic categories have been reported to the World Health Organization (WHO) and include medicines, vaccines and in vitro diagnostics. Anti-malarials and antibiotics are among the most commonly reported substandard and falsified medical products. Both generic and innovator medicines can be falsified, ranging from very expensive products for cancer to very inexpensive products for the treatment of pain (WHO, 2018).

Substandard and falsified medical products can be found in illegal street markets, via unregulated websites, through to pharmacies, clinics and hospitals. An estimated one in ten medical products in low- and middle-income countries is substandard or falsified. Substandard and falsified medical products contribute to antimicrobial resistance and drug-resistant infections (WHO, 2018).

Falsified medical products may contain no active ingredient, the wrong active ingredient or the wrong amount of the correct active ingredient. They are also commonly found to contain corn starch, potato starch, or chalk. Some substandard and falsified medical products have been found to be toxic with either fatal levels of the wrong active ingredient or other toxic chemicals (WHO, 2018).

Substandard and falsified medical products are often produced in very poor and unhygienic conditions by unqualified personnel and contain unknown impurities and are sometimes contaminated with bacteria (WHO, 2018).

Substandard and falsified medical products are difficult to detect. They are often designed to appear identical to the genuine product and may not cause an obvious adverse reaction, however, they will often fail to properly treat the disease or condition for which they were intended and can lead to serious health consequences including death (WHO, 2018).

Preliminary – Corrections Pending

The WHO has adopted definitions of substandard, unregistered/unlicensed and falsified medical products (WHO, 2018):

- Substandard (also called 'out of specification') medical products are authorised medical products that fail to meet either their quality standards or specifications, or both.
- Unregistered/unlicensed medical products are those that have not undergone evaluation and/or approval by the national or regional regulatory authority for the market in which they are marketed/distributed or used, subject to permitted conditions under national or regional regulation and legislation.
- Falsified medical products are those that deliberately/fraudulently misrepresent their identity, composition, or source.

Metrics and numeric limits

Not available.

Key relevant UN convention/multilateral treaty

Not available.

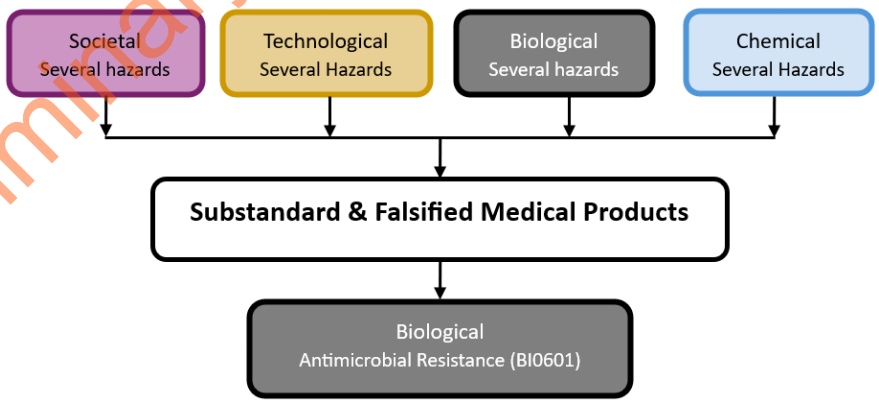
Examples of hazard drivers, impacts and risk management

Hazard Drivers: Many countries and the media frequently report successful action against manufacturers of substandard and falsified medical products. Some reports refer to large-scale manufacturing and others to small back-street operations. With the availability of tableting machines, ovens, specialist equipment, ingredients and packaging materials, clandestine manufacturing facilities are quick and easy to assemble (WHO, 2018).

Impacts: No country remains untouched by this issue, from North America and Europe through to sub-Saharan Africa, South East Asia, and Latin America. What was once considered a problem limited to developing and low-income countries has now become an issue for all. With the exponential increase in internet connectivity, those engaged in the manufacture, distribution and supply of substandard and falsified medical products have gained access to a global marketplace. However, it is in low- and middle-income countries and those in areas of conflict, or civil unrest, where healthcare systems are weak or non-existent that bear the greatest burden of substandard and falsified medical products. Substandard and falsified medical products are most likely to reach patients in situations where there is constrained access to quality and safe medical products, poor governance and weak technical capacity (WHO, 2018).

The falsification of medical products is a crime affecting all regions of the world and addressing it requires greater cooperation along the entire supply chain (WHO, 2017).

Multi-hazard Context: The figure below summarises common interactions between substandard and falsified medical products and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring substandard and falsified medical products. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Informa	World Health Organization (WHO)
How is the Hazard Observed/Monitored/Forecast?	WHO Global Surveillance and Monitoring System

Risk Management: The Member State Mechanism is the global platform where countries can convene, coordinate, decide and

Preliminary – Corrections Pending

organise actions to address substandard and falsified medical products. It was established in order to protect public health and promote access to affordable, safe, efficacious and quality medical products, through effective collaboration between Member States and the WHO to prevent and control substandard and falsified medical products and associated activities (WHO, 2018).

The structured reporting system allows for a fast response to emergencies and the issue of alerts in the most serious cases. It also facilitates in-depth analyses of the medical products most at risk, the vulnerabilities and weaknesses in health systems, the harm caused to public health and the need for investment, training and stronger regulations and standards (WHO, 2018).

The WHO provides guidance (WHO, 2018) for identifying substandard and falsified medical products, both as the products but also for those purchased from the Internet.

- Identifying a substandard or falsified medical product: Some falsified medical products are almost visually identical to the genuine product and very difficult to detect. However, many can be identified by examining the packaging for condition, spelling mistakes, or grammatical errors; checking the manufacture and expiry dates and ensuring any details on the outer packaging match the dates shown on the inner packaging; ensuring the medicine looks correct, is not discoloured, degraded or has an unusual smell; discussing with your pharmacist, doctor or other healthcare professional as soon as possible if you suspect the product is not working properly or you have suffered an adverse reaction; and reporting suspicious medical products to your National Medicines Regulatory Authority.
- Substandard and falsified medical products and the Internet: Unregulated websites, social media platforms, and smartphone applications can also be direct conduits of substandard and falsified medical products. Risks to consumers are significantly increased when obtaining medical products from unlicensed and unregulated sources.

To support countries in enacting or strengthening domestic legislation in this area and in protecting public health, the United Nations Office on Drugs and Crime (UNODC) released a guide to good legislative practices on combating falsified medical product-related crime (UNODC, 2019).

Early Warning Systems In 2013, the WHO launched the Global Surveillance and Monitoring System to encourage countries to report incidents of substandard and falsified medical products in a structured and systematic format, to help develop a more accurate and validated assessment of the problem. The system provides technical support in emergencies, links incidents between countries and regions, and issues WHO medical product alerts; and gathers a validated body of evidence to more accurately demonstrate the scope, scale and harm caused by substandard and falsified medical products and identify vulnerabilities, weaknesses and trends (WHO, 2018).

References

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Coordinating agency or organisation

World Health Organization (WHO); International Union of Pure and Applied Chemistry (IUPAC).

Preliminary – Corrections Pending

CH0603 / CHEMICAL / Chemical Hazards in Food and Pharmaceuticals

Methanol

Definition

Methanol is a colourless, volatile liquid. Categorized as an alcohol, methanol is commonly used as a solvent and reagent in an array of industrial applications. Outbreaks of methanol poisoning most commonly arise from the consumption of adulterated or informally produced spirit drinks (adapted from NCBI, 2024 and WHO, 2014).

References

NCBI, 2024. PubChem Compound Summary for CID 887, Methanol. National Center for Biotechnology Information (NCBI). https://pubchem.ncbi.nlm.nih.gov/compound/Methanol Accessed 30 Jun 2024.

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Preliminary - Corrections Pending

Annotations

GHS Classification (UNECE, 2023)

Synonyms

CH_3OH; MeOH; Methyl alcohol; Wood alcohol; Hydroxymethane.

Additional scientific description

Methanol belongs to the class of organic compounds known as primary alcohols. Methanol's chemical formula is CH_3OH and is the simplest aliphatic alcohol, comprising a methyl and a hydroxyl group. It has a role as a solvent and reagent in many industrial processes; it is soluble in water and many organic solvents (NCBI, 2024).

Methanol is a widely available chemical and can be found in various household products, including varnishes, antifreeze, windscreen wash, and fuel for model aircraft. It is also used as a denaturant for ethanol. Globally, approximately 225 million litres of methanol are used each day (WHO, 2014a; WHO, 2014b).

Methanol is primarily produced by catalytic synthesis of synthesis gas (Syngas, a mixture of hydrogen and carbon monoxide) under high-temperature and pressure conditions. Another production method involves the gasification of biomass (Liu, 2023).

Methanol is well-absorbed through the gastrointestinal tract and is also absorbed through the skin and by inhalation. It has a relatively low intrinsic toxicity. However, it is metabolized to highly toxic compounds, including formaldehyde and formic acid, which can cause blindness, central nervous system (CNS) depression, gastrointestinal disturbances, and severe metabolic disturbances that can be life-threatening. Humans have a limited ability to detoxify formic acid, and this metabolite therefore accumulates and causes toxic effects (Nekourar, 2021; WHO, 2014a).

Metrics and numeric limits

Occupational Exposure Limits (OEL) published by the United States Occupational Safety and Health Administration (OSHA) and the European Chemicals Agency (ECA) include a time weighted average (TWA) permissible 8-hour exposure limit of 200 ppm (260 mg/m^3) in air (OSHA, 2023; ECA, 2023).

The toxic dose of methanol varies depending on the individual and on the provision of treatment. Blood methanol concentrations above 0.500 mg/mL are associated with severe toxicity, and concentrations above 1.500-2.000 mg/mL can lead to death in untreated patients. Because patients with methanol poisoning often need intensive medical care, outbreaks of methanol poisoning can rapidly overwhelm medical facilities (WHO, 2014a).

Methanol and its formic acid metabolite were identified in the post-mortem samples of nineteen individuals who were fatally poisoned by methanol consumption during a three-month period in 2022. The compounds were identified in biological fluids (urine, vitreous humour, bile, and cerebral spinal fluid) and tissues (muscle, kidney, liver, spleen, lung, and brain), demonstrating a wide distribution throughout the body of both methanol and formic acid. For methanol, the average concentration range was 2.45-3.36 mg/mL and 2.02-3.42 mg/g for biological fluids and tissues, respectively. For formic acid, the average concentration range was 0.43-2.94 mg/mL and 0.44-0.67 mg/g for biological fluids and tissues, respectively (Tomsia 2022).

Key relevant UN Conventions and multilateral treaties

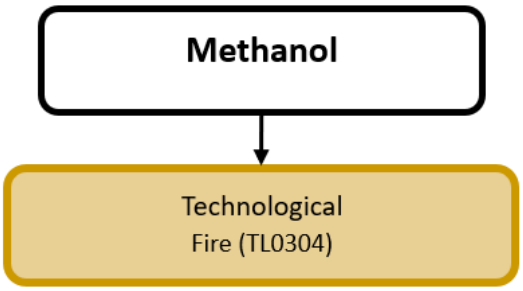
None identified.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: The informal and illicit (undocumented) production of alcoholic drinks is practiced in many parts of the world, including in countries where alcohol is banned. Alcohol produced in this format is not taxed and lacks government and market oversight. Some common names for these drinks include hooch/moonshine (USA), chang'aa/kumi kumi (Kenya), tonto/waragi (Uganda), tuak/tapai (Malaysia), samogon (Russia), and talla (Ethiopia). Such drinks are often sold in unlabelled containers in markets and at illegal drinking venues. Illicitly or informally produced alcohol may also be sold in legitimate bars, particularly in some tourist areas. Some illicitly produced drinks are made to appear legitimate through bottle design and labelling; consumers can be misled into believing that they are buying a genuine brand of alcohol. Bottles may be sold in shops, markets and bars, often at what appears to be a discounted price (Manning, 2021; WHO, 2014a).

Impacts: Outbreaks of methanol poisoning arise from the consumption of adulterated counterfeit or informally produced spirit drinks. There have been a multitude of outbreaks between 1963-2020, including in the following countries: Bangladesh, Botswana, Cambodia, Canada, China, Costa Rica, Czech Republic, Dominican Republic, Ecuador, El Salvador, Estonia, Haiti, Honduras, India, Indonesia, Iran, Italy, Kenya, Libya, Madagascar, Malaysia, Mongolia, Nicaragua, Nigeria, Norway, Pakistan, Papua New Guinea, Poland, Russia, Saudi Arabia, Serbia, Spain, Sudan, Taiwan, Tunisia, Turkey, and Uganda. The size of these outbreaks has ranged from 10 to greater than 800 victims, with hundreds of hospitalizations and fatalities occurring within individual outbreaks in some instances (Eskandrani, 2022; Manning, 2021; Tomsia, 2022).

Multi-hazard Context: The figure below summarises common interactions between methanol and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring methanol. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Preliminary – Corrections Pending

Which institution(s) produce(s) Disast Data/Information?	World Health Organization (WHO)
How is the Hazard Observed/Monitor Forecast?	Monitoring emergency rooms and hospitals for cases of methanol poisoning and recording of si and symptoms of methanol consumption Centralized data collection and rapid reporting system, e.g., in the hospital setting and at poisor control centres to facilitate ease of communication between health agencies and public health officials

Risk Management: The WHO guidance on methanol poisoning outbreaks (WHO, 2014a) recommends the following risk management for prevention and control:

What can individuals do to protect themselves?

- Refrain from purchasing or producing illegal alcoholic drinks.
- Be suspicious about alcoholic drinks offered for sale in informal settings that are not licensed to sell alcohol, such as market stalls, and/or that are offered at a cheap price.
- Do not buy alcoholic drinks sold in unlabelled containers.
- Check branded products for labels that are poorly printed or with typographical errors, or bottles with broken seals. Do not buy these.
- Be aware of the symptoms of methanol poisoning and seek medical attention immediately if exposure is suspected.

What measures can countries take?

- Put in place a national strategy and legal framework to reduce the harmful use of alcohol.
- Use public health campaigns to promote awareness of the dangers of informally produced and illicit alcoholic drinks. These can be targeted towards particular high-risk groups, such as alcohol-dependent individuals and tourists.
- Since early recognition of an outbreak is vital to improve outcomes, ensure that medical professionals are trained in the diagnosis and management of methanol poisoning.
- Where mass methanol poisonings have the potential to occur, establish a protocol for the management of these outbreaks.
- The ability of laboratories to undertake blood methanol analysis can help identify and guide the clinical management of poisoned patients.
- Ensure accessible and affordable treatment is available for all, including antidotes (e.g., fomepizole, ethanol).
- Provide support to victims, particularly those at risk of recurrent events, such as alcohol-dependent individuals.

The WHO is committed to reducing the health burden resulting from the harmful use of alcohol (WHO, 2014b). In 2010, the World Health Assembly endorsed a global strategy to reduce the harmful effects of alcohol. Ten recommended target areas were identified, including one addressing the need to reduce the public health impact of illicit alcohol and informally produced alcohol. Several policy options and interventions are suggested, including: developing good quality control with regard to production and distribution of alcoholic beverages; regulating sales of informally produced alcohol and bringing it into the taxation system; creating an efficient control and enforcement system, including tax stamps; developing or strengthening tracking and tracing systems for illicit alcohol; ensuring necessary cooperation and exchange of relevant information on combating illicit alcohol among authorities at national and international levels; and issuing relevant public warnings about contaminants and other health threats from informal or illicit alcohol (WHO, 2014b).

Critical elements of Early Warning Systems for methanol poisoning should involve several components to detect and respond to potential outbreaks, especially in contexts where methanol poisoning is a recurrent issue.

- Provision of training for healthcare professionals to recognize and treat methanol poisoning.
- Monitoring emergency rooms and hospitals for cases of methanol poisoning and recording of signs and symptoms of methanol consumption.
- Creating a centralized data collection and rapid reporting system, e.g., in the hospital setting and at poison control centres, to facilitate ease of communication between health agencies and public health officials.
- Rapid testing of biological specimens from individuals suspected of methanol intoxication.
- Rapid testing of contaminated alcohol samples.
- Issuing public warnings and health advisories through mainstream media and social media platforms. Educating the public about the dangers of consuming non-commercial/unregulated alcohol products and recognizing the symptoms of methanol poisoning.
- Creating platforms for the public to report symptoms of potential poisonings electronically and the ability to receive

Preliminary – Corrections Pending

immediate advice from a healthcare professional.

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Coordinating agency or organisation

World Health Organization (WHO).

International Union of Pure and Applied Chemistry (IUPAC

Preliminary – Corrections Pending

CH0604 / CHEMICAL / Chemical Hazards in Food and Pharmaceuticals

Opioids and Other Psychoactive Substances

Definition

Psychoactive substances are chemical compounds that can lead to physical or psychological dependence when consumed repeatedly, often altering brain function and behaviour. Overdose and overuse have caused significant public health concerns due to their potential to cause a wide range of adverse health effects. Addictive substances include alcohol, nicotine, (synthetic) opioids, (natural) opiates, stimulants, and certain sedatives, amongst others.

Reference

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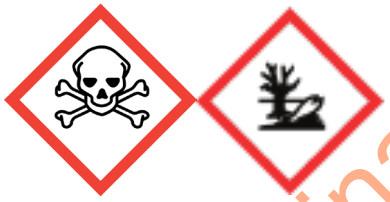
Preliminary – Corrections Pending

Annotations

GHS Classification (UNECE, 2023)



Synonyms

Ethanol, nicotine (3-[(2S)-1-methylpyrrolidin-2-yl]pyridine)

Additional scientific description

Opiates are drugs derived from opium, which are alkaloids naturally found in the opium poppy plant Papaver somniferum that upon extraction typically yield (-)-morphine (10-15%), (-)-codeine (3-methylmorphine, 3-4%), and (-)-thebaine (1-2%). On the other hand, the term opioids is used for all substances, either natural or synthetic, that bind to opioid receptors, including the antagonists (NIDA, 2024).

These substances have been consumed as medicine for the treatment of pain, but also recreationally for the euphoria and hallucinations that they provoke. The uncontrolled use of these substances (opioid overdose) has resulted in the present so-called “opioid” epidemic, responsible for around 80% of the 600,000 deaths reported worldwide in 2019. Common side effects include tolerance and dependence, itching, pupil constriction, constipation, nausea and vomiting, and, most importantly, respiratory depression. The major offenders are synthetic opioids other than methadone, followed by psychostimulants, and finally heroin (WHO, 2023).

Heroin, an acetylated derivative of morphine, was first made in 1874 and later first manufactured in 1898. The acetylation makes the molecule less polar than morphine, so that it crosses the Blood Brain Barrier (BBB) more easily, and once inside the brain, enzymes hydrolyse the esters quite easily resulting in a faster delivery of morphine, which is the actual drug responsible

for the observed intense euphoric effects (NIDA, 2011)

Prescription opioids are the leading offenders in drug addiction by several mechanisms, such as redirection, over-prescription, or doctor shopping (Skolnick, 2018). Some prescription opioids include hydrocodone bitartrate, oxycodone hydrochloride, oxymorphone hydrochloride, morphine sulfate extended-release, and codeine. One of the main contributors has been the oxycodone hydrochloride pills, where over-prescription of opioids leads to overdoses and addiction.

Other less common and simpler opioids are the morphinans, which are more potent and longer lasting than their morphine counterparts, with a higher toxicity. Included in the simpler structures, made by simplification strategies, are the 6,7-benzomorphans (Metazocine/Pentazocine), the 4-phenylpiperidines, and methadone, which is used to treat drug addicts.

One of the opioids of most recent concern, by its potency and overwhelming abuse, is fentanyl and its many analogues. Fentanyl was first synthesized in the early 1960s and is 50-100 times more potent than heroin, 2-3 mg of the opioid can be fatal (Stanley, 2005).

When used under strict medical supervision, fentanyl is safe and appropriate. Fentanyl use mainly relies on treating patients who have become tolerant to opioid therapy for cancer pain and need something stronger. The range of compound amount typically used can be between 50 – 1200 µg (mcg) in different forms of delivery or concentrations. Among the fentanyl approved drugs, we should mention the transdermal patches, sublingual tablets, lollipops, and the injectable forms. The use of fentanyl in colonoscopy studies (25-50 µg) is also common, safe, and significantly shortens recovery times (Stanley, 2005).

Misuse of fentanyl sparked by the illicit market has led to the detection of several forms of the drug, mainly as illegal pills, in different forms and combinations. The ease of synthesizing the derivatives coupled with the proliferation of clandestine laboratories with no quality control has resulted in haphazard combinations of the drug and millions of deaths. Derivatives of considerable importance include furanyl fentanyl, acetylfentanyl, fluorofentanyl (different ring substitutions with the para derivative being more abused), and the extremely potent carfentanil, among many others. Carfentanil, by itself, is an animal tranquilizer 100 times more potent than fentanyl and 10,000 times more potent than morphine, and is used in veterinary medicine for the immobilization of large animals such as rhinoceros or elephants. Unfortunately, it has also found its way into street drugs. WHO continues to monitor several fentanyl analogues through its surveillance system for new psychoactive substances, alerting countries to the potential dangers associated with these substances (Han, 2019).

More recently, fentanyl and xylazine combinations have been detected in the streets, which has become an emerging threat since July 2023. Xylazine is used in veterinary medicine (mainly with horses) as an anaesthetic, but its misuse in humans causes euphoric effects, muscle relaxation, and trouble breathing. In addition, users can develop chronic wounds that are difficult to heal and painful. Xylazine is an Alpha-2 agonist, not an opioid, and as such, naloxone does not reverse its effects. Presently, there is no approved antagonist that can reverse its deleterious effects. Other opioids, such as nitazines, are also dangerous, as is accidental or deliberate contamination of heroin by fentanyls or nitazenes, which can lead to unexpected toxicity and accidental overdose (Jain 2024).

Alcohol and nicotine are two widely used substances with addictive properties that can have severe consequences for health and well-being. Alcohol is a depressant that enhances the release of dopamine in the brain, creating feelings of relaxation and euphoria. Chronic use can lead to tolerance, dependence, and withdrawal symptoms such as anxiety, tremors, and seizures. Long-term alcohol misuse increases the risk of liver disease, cardiovascular and neurological damage (NIAAA, 2021).

Nicotine, found in tobacco products, is a highly addictive stimulant that rapidly affects the brain, triggering the release of dopamine and reinforcing the habit. Prolonged use of nicotine leads to dependence and withdrawal symptoms like irritability, anxiety, and cravings. It is a major risk factor for respiratory diseases, heart disease, and various cancers, particularly lung cancer. The addictive nature and health risks of both substances underscore the need for effective prevention and support for individuals seeking to overcome their use (Benowitz , 2010).

Metrics and numeric limits

Opioids: Prescription Guidelines

1. **Morphine Milligram Equivalents (MME):** The Centers for Disease Control and Prevention (CDC) recommends avoiding doses of **≥90 MME/day** for chronic pain when possible, as higher doses increase the risk of overdose. (CDC, 2022).
2. **Duration of Use:**
    1. For acute pain, prescriptions should generally not exceed **3-7 days**, as longer durations significantly increase the risk of dependency (Dowell, 2016).
    2. **Naloxone Prescription:** Co-prescription of naloxone is recommended for patients at higher risk of opioid overdose, such as those on **≥50 MME/day** (Dowell, 2016).

Alcohol: Moderate Drinking Guidelines:

1. **United States Dietary Guidelines (2020-2025):**

Preliminary – Corrections Pending

- Moderate drinking is defined as:
  - **Up to 1 drink per day for women.**
  - **Up to 2 drinks per day for men.**
  - One standard drink is: **14 grams of pure alcohol**, equivalent to:
    - 12 oz of beer (5% alcohol).
    - 5 oz of wine (12% alcohol).
    - 1.5 oz of distilled spirits (40% alcohol). (U.S. Department of Health and Human Services, 2020).

2. **Weekly Limits:**
   - The National Institute on Alcohol Abuse and Alcoholism (NIAAA) suggests: **No more than 7 drinks per week for average women** and **14 drinks per week for average men** to reduce risks of alcohol-related harm (NIAAA, 2021). Women who are pregnant or planning a pregnancy should not drink alcohol.

Key relevant UN convention/multilateral treaty

Several key United Nations conventions and multilateral treaties address issues related to the control of addictive substances such as opioids, alcohol, and nicotine. Here's an overview:

Opioids:

- **Single Convention on Narcotic Drugs (1961, as amended in 1972):** Establishes international control over narcotic drugs, including opioids, to limit their use to medical and scientific purposes while preventing illicit production and trafficking. Administered by the International Narcotics Control Board (INCB).
- **Convention on Psychotropic Substances (1971):** Aims to control psychotropic substances, including certain synthetic opioids, to prevent misuse while ensuring their availability for legitimate purposes.
- **United Nations Convention against Illicit Traffic in Narcotic Drugs and Psychotropic Substances (1988):** Strengthens international cooperation to combat illicit drug trafficking, focusing on opioids and their precursors.

Alcohol: No specific global treaty regulates alcohol in the same way as narcotics, but alcohol is indirectly addressed under health and public policy frameworks:

- **Global Strategy to Reduce the Harmful Use of Alcohol (2010):** A non-binding framework by the World Health Organization (WHO) encouraging member states to implement policies addressing alcohol misuse.
- **WHO Framework Convention on Tobacco Control (2003):** Although focused on tobacco, this treaty includes measures related to the dual use of substances like alcohol and tobacco, recognizing the intersection of public health challenges.

Nicotine (Tobacco): WHO Framework Convention on Tobacco Control (FCTC, 2003): The first legally binding health treaty under WHO, focusing on reducing tobacco consumption and exposure to nicotine products. Includes measures on advertising bans, tax policies, and restrictions on public smoking.

Examples of hazard drivers, impacts and risk management

Hazard Drivers for Opioid Dependence: There are a number of risk factors for opioid overdose as described by WHO (WHO, 2023). These include:

- Having an opioid use disorder;
- Taking opioids by injection;
- Resumption of opioid use after an extended period of abstinence (e.g. following detoxification, release from incarceration, cessation of treatment);
- Using prescription opioids without medical supervision;
- High prescribed dosage of opioids (more than 100 mg of morphine or equivalent daily).
- Using opioids in combination with alcohol and/or other substances or medicines that suppress respiratory function, such as benzodiazepines, barbiturates, anaesthetics, or some pain medications; and
- Having concurrent medical conditions such as HIV, liver or lung diseases or mental health conditions.

Males, people of older age and people with low socio-economic status are at higher risk of opioid overdose than women, people of young age groups and people with higher socio-economic status.

Hazard Drivers for Alcohol Dependence (Mustafa 2024)**:**

A. Biological and Genetic Factors
   1. Family History of Addiction: Having a parent or close relative with alcohol addiction increases the risk due to genetic predisposition.

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2. Neurochemical Imbalances: Altered levels of neurotransmitters, such as dopamine, can make individuals more susceptible to addiction.
3. Early Onset of Drinking: Initiating alcohol consumption at a young age is linked to a higher risk of developing dependence.

B. Psychological Factors

1. Mental Health Disorders: Conditions like depression, anxiety, or PTSD often coexist with alcohol misuse.
2. Stress and Coping Mechanisms: Using alcohol as a coping mechanism for stress increases the risk of dependency.

C. Social and Environmental Factors

1. Peer Pressure: Strong influence from peers can lead to habitual alcohol use.
2. Cultural Norms: Societal attitudes that normalize or glamorize drinking can increase risk.
3. Availability and Accessibility: Easy access to alcohol significantly raises the likelihood of abuse.

D. Other Factors

1. Trauma and Adverse Childhood Experiences (ACEs): Early-life trauma is strongly associated with addiction risks.
2. Lack of Education: Poor understanding of the risks associated with excessive alcohol consumption can contribute.

Hazard Drivers for nicotine dependence (Benowitz 2010)**:**

A. Biological and Genetic Factors

1. Genetic Susceptibility: Genetic variations can affect how the body processes nicotine and the likelihood of addiction.
2. Adolescent Brain Development: Young brains are particularly sensitive to the effects of nicotine, increasing addiction risks.

B. Psychological Factors

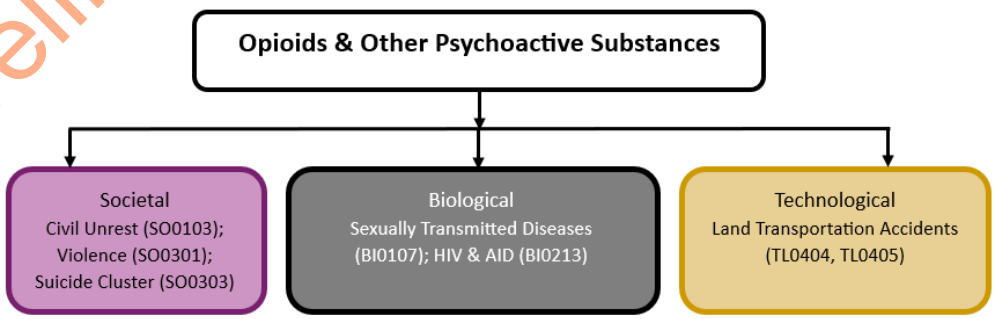
1. Coexisting Mental Health Conditions: Anxiety and depressive disorders are common among individuals with nicotine dependence.
2. Impulsivity and Sensation-Seeking: Personality traits that favour risky behaviours are linked to higher nicotine use.

C. Social and Environmental Factors

1. Peer and Social Influence: Adolescents are particularly vulnerable to smoking due to peer pressure.
2. Marketing and Advertising: Targeted advertisements and media representations glamorizing smoking contribute significantly.
3. Family Smoking Habits: Exposure to smoking within the household normalizes the behaviour and increases risk.

Impacts: Opioids are the deadliest drug type. According to the US Drug Enforcement Administration (DEA) seven out of ten illegal fake pills in the streets with fentanyl contain a potentially lethal dose (at least 2 mg of fentanyl). Drug traffickers are using fake pills to exploit the opioid crisis and prescription drug misuse. In 2022, an estimated 110,757 people died by drug poisoning in the United States. Fentanyl, the synthetic opioid most found in fake pills, is the primary driver in this alarming increase in poisoning deaths. According to WHO estimates, approximately 125,000 people died of opioid overdose in 2019.

Multi-hazard Context: The figure below summarises common interactions between opioids & other addictive substances and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: No Information Available

Risk management: Detection of fentanyl is difficult since it has no taste, no smell, and cannot be distinguished by touch. Some recent detection efforts include fentanyl test strips (FTS) and advanced handheld Raman spectrometers analysers such as Tactic ID or TruNarc™, which are narcotic analysers. Portable mass spectrometers may also prove useful. FTS are small strips of paper that can detect the presence of fentanyl in different kinds of drugs and drug forms and can inform people about the presence of fentanyl so they can take steps to reduce their risk of overdose. There is also a commercial strip version that

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combines both fentanyl and xylazine in one test strip. The Raman spectrometers allow the first responders to quickly and accurately identify key drugs of abuse anywhere at any time without opening the containers (Crocombe 2023).

Uncontrolled opioid use can lead to dependence, both physical and mental. There are observable withdrawal symptoms and a sustained mental need for the drug or substance. An overdose needs immediate attention due to its fatal consequences. The best is the use of an antidote; more commonly now used is naloxone, which is an antagonist of the opioid receptors and reverses the overdose (van Dorp, 2007). Naloxone comes in different forms, but the most common is the nasal spray with similar action times as an intramuscular injection. Sometimes several doses are needed to reverse a strong opioid overdose. WHO recommends that naloxone be made available to people likely to witness an opioid overdose, as well as training in the management of opioid overdose. More recently, in the US, a similar delivery method has been manufactured with Nalmefene with the advantage of having a longer half-life (11.4 hrs) vs. 1.2 hrs than naloxone (Green 2024).

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WHO recommends the use of a range of treatment options for opioid dependence. These include opioid agonist maintenance treatment (with medicines such as methadone and buprenorphine), which has the strongest evidence of effectiveness and cost-effectiveness, as well as psychosocial treatment and support, and pharmacological treatment with opioid antagonists (such as naltrexone).

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Coordinating agency or organisation

World Health Organisation (WHO)

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0605 / CHEMICAL / Chemical Hazards in Food and Pharmaceuticals

Marine Toxins

Definition

Marine toxins (biotoxins) are naturally occurring, toxic substances, mostly caused by certain types of marine organisms, such as toxic algae, but also by bacteria. These toxins can accumulate in fish and shellfish, causing significant public health concerns due to their potential to cause a wide range of adverse health effects.

Reference

WHO, 2024. Natural Toxins in Food (2024). World Health Organisation (WHO). https://www.who.int/news-room/fact-sheets/detail/natural-toxins-in-food Accessed 16 June 2024.

Annotations

GHS Classification (UNECE, 2023)

Synonyms

Algal bloom toxins; biotoxins; ichthyotoxins; phycotoxins; seafood toxins; shellfish toxins.

Additional scientific description

Marine toxins are primarily produced by algae or bacteria and are concentrated in contaminated fishery and aquaculture products. When people consume these contaminated products, depending on the toxin, the symptoms can be diarrheic, paralytic, amnesic, or neurologic, some of which result in high mortality and long-term morbidity (Sobel and Painter, 2005).

Routine clinical diagnostic tests are not available for these toxins; diagnosis is based on clinical presentation and a history of eating fishery and aquaculture products in the preceding 24 hours (Sobel and Painter, 2005). There is no antidote for any of the marine toxins, and supportive care is the mainstay of treatment. Paralytic shellfish poisoning and puffer fish poisoning can cause death within hours of consuming the toxins and may require immediate intensive care (Sobel and Painter, 2005).

A Joint FAO/IOC/WHO expert meeting classified the toxins into eight groups based on their chemical structure (FAO/WHO, 2016): the Azaspiracid (AZA) group, Brevetoxin group, Cyclic Imines group, Domoic Acid (DA) group, Okadaic Acid (OA) group, Pectenotoxin (PTX) group, Saxitoxin (STX) group, and Yessotoxin (YTX) group.

The Food and Agriculture Organization of the United Nations (FAO) reports that they can also be classified by the type of poisoning they cause (FAO, 2004):

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Paralytic shellfish poisoning (PSP) (FAO, 2004)**:** PSP poisoning in humans is caused by ingestion of shellfish containing PSP toxins, which accumulate by shellfish grazing on algae producing these toxins.

- **Symptoms:** slight tingling or numbness to complete respiratory paralysis.
- In fatal cases, respiratory paralysis occurs within 2 to 12 hours of consuming the PSP-contaminated food.

Diarrhoeic shellfish poisoning (DSP) (FAO, 2004): In humans, DSP poisoning is caused by the ingestion of contaminated bivalves such as mussels, scallops, oysters, or clams. The fat-soluble DSP toxins accumulate in the fatty tissue of the bivalves.

- **Symptoms:** diarrhoea, nausea, vomiting and abdominal pain starting 30 minutes to a few hours after ingestion and complete recovery occurs within three days.
- DSP toxins can be divided into different groups depending on chemical structure - the first group, acidic toxins, includes okadaic acid and its derivatives named dynophysistoxins; the second group, neutral toxins, consists of polyether-lactones of the pectenotoxin group; the third group includes a sulphated polyether and its derivatives the yessotoxins.

Amnesic shellfish poisoning (ASP) (FAO, 2004): In humans, ASP is also known as domoic acid poisoning (DAP) because amnesia is not always present.

- **Symptoms:** abdominal cramps, vomiting, disorientation and memory loss (amnesia).
- The causative toxin (the excitatory amino acid domoic acid or DA) was produced by the diatom species Pseudo-*nitzschia pungens f. multiseries* (*Nitzschia pungens f. multiseries*).

Neurotoxic shellfish poisoning (NSP) (FAO, 2004): NSP is caused by polyether brevetoxins produced by the unarmoured dinoflagellate *Gymnodinium breve* (also called *Ptychodiscus breve*, since 2000 called *Karenia brevis*) are toxic to fish, marine mammals, birds, and humans, but not to shellfish.

- An unusual feature of G. breve is the formation by wave action of toxic aerosols, which can lead to asthma-like symptoms in humans.

Azaspiracid shellfish poisoning (AZP) (FAO, 2004): In November 1995, at least eight people in the Netherlands became ill after eating mussels (*Mytilus edulis*) cultivated at Killary Harbour, Ireland. Although the symptoms resembled those of diarrhoeic shellfish poisoning (DSP), concentrations of the major DSP toxins were very low.

- The known organisms producing DSP toxins were not observed in water samples collected at that time.
- In addition, a slowly progressing paralysis was observed in the mouse assay using the mussel extracts. These neurotoxic symptoms were different from typical DSP toxicity.
- It was then that azaspiracid (formerly called Killary Toxin-3 or KT3) was identified and the new toxic syndrome was called azaspiracid poisoning (AZP).

Ciguatoxins causing ciguatera poisoning (CP) (FAO, 2004): The name ciguatera was given by Don Antonio Parra in Cuba in 1787 to intoxication following ingestion of the 'cigua', the Spanish trivial name of a univalve mollusc, Turbo pica, reputed to cause indigestion.

- The term cigua was somehow transferred to an intoxication caused by the ingestion of coral reef fish species.
- The causative toxins, the ciguatoxins, accumulate through the food chain, from small herbivorous fish grazing on the coral reefs to organs of the bigger carnivorous fish that feed on them.

Metrics and numeric limits (FAO/WHO, 2015)

The maximum level per kilogram of mollusc flesh for the different toxin groups is as follows:

- **Saxitoxin (STX) group:** ≤ 0.8 mg of saxitoxin equivalent
- **Okadaic acid (OA) group:** < 0.16 mg of okadaic acid equivalent
- **Domoic acid (DA) group:** < 20 mg of domoic acid
- **Brevetoxin (BTX) group:** < 200 mouse units or equivalent
- **Azaspiracid (AZA) group:** < 0.16 mg

Key relevant UN convention/multilateral treaty

Food and Agricultural Organisation of the United Nations (FAO) and World Health Organisation (WHO), The Codex Alimentarius Commission (CAC) (FAO/WHO, 2024)

United Nations Environment Programme (UNEP), The Convention on Biological Diversity (CBD) (CBD, 2024)

International Maritime Organisation, The International Convention for the Prevention of Pollution from Ships (MARPOL) (IMO, 1973)

United Nations Environment Programme (UNEP), Stockholm Convention on Persistent Organic Pollutants (POPs) (UNEP, 2019).

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United Nations Oceans & Law of the Sea (UNOLS), The United Nations Convention on the Law of the Sea (UNCLOS) (UNOLS, 1982)

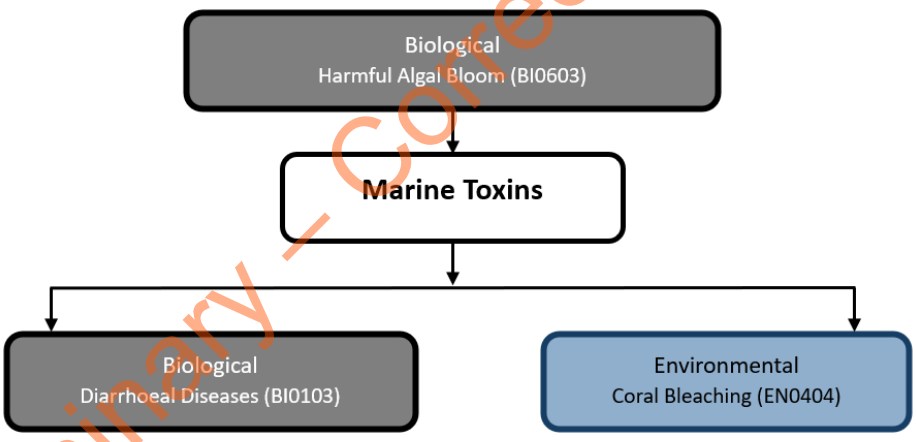
Examples of hazard drivers, impacts and risk management

Hazard Drivers: The substantial increase in the consumption of fishery and aquaculture products in recent years, together with globalisation of trade, has increased the potential for human exposure to these marine biotoxins. Monitoring programmes for the toxins and their source organisms, and rapid notification of food safety issues by the authorities is essential to avoid foodborne intoxications. Toxic cyanobacteria can also occur in freshwater, affecting water supplies (He 2016). Extensive environmental monitoring and sometimes seasonal quarantine of a harvest are used to reduce the risk of exposure (Sobel and Painter, 2005).

It is difficult to predict when a bloom will develop. Climatic and environmental conditions, such as changes in salinity, rising water temperature, increased nutrient levels and sunlight, can influence population growth. Other drivers of marine toxins include climate change and ballast water discharge. Rising sea temperatures and changes in ocean circulation patterns cause warmer temperatures and altered currents can enhance algal growth and toxin production (EPA, 2024). Ships discharging ballast water into oceans and seas introduce non-native, potentially toxic algal species into waters (IMO, 2019). Excessive nutrients can also lead to the proliferation of toxin-producing algae (NOS, 2023).

Impacts of marine toxins include human health effects such as gastrointestinal, neurological, and cardiovascular issues and in severe cases, death. Marine and freshwater ecosystems are also affected, including disruption of food webs, fish kills, and loss of biodiversity. Economic impacts include loss of revenue from fisheries, tourism, and aquaculture, as well as increased public health costs (FAO, 1999).

Multi-hazard Context: The figure below summarises common interactions between marine toxins and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring marine toxins. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	European Commission (EC); National Oceanic and Atmospheric Administration (NOAA); environmental agencies
How is the Hazard Observed/Monitored/Foreca	Monitoring and remote sensing; prediction modelling; communication

Risk Management includes the establishment of national monitoring programmes for marine biotoxins and their source organisms, by methods such as regular sampling and testing of water and seafood for toxins, and their continuous update to include new and emerging toxins when necessary (WHO, 2017). Implementing regulatory limits and standards, as well as informing the public about risks and safe consumption practices, are risk management protocols that should be implemented. Other mitigation strategies include reducing nutrient runoff through best management practices (BMPs) in agriculture, and improving sewage treatment; also reducing greenhouse gas emissions, protecting marine environments (EPA, 2023; UNCC, 2024).

Preliminary – Corrections Pending

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Preliminary – Corrections Pending

Coordinating agency or organisation

Food and Agriculture Organization of the United Nations (FAO), World Health Organization (WHO)

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0901 / CHEMICAL / Other Chemical Hazards

Corrosive Substances

Preliminary – Corrections Pending

Definition

Corrosive substances are materials, such as strong acids and strong bases, that, through chemical reactions, cause visible destruction of biological tissues and other materials. Acids are substances that have a high tendency to donate protons when completely dissociating into ions in water, whereas strong bases are substances that accept protons when completely dissociating into ions in water. Both are highly corrosive and catalyse the decomposition of biological molecules. (Burrows et al., 2021)

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Annotations

GHS Classification (UNECE, 2023)

Synonyms

Mineral acids; inorganic acids; strong inorganic acids; highly acidic solutions; Lewis acid; electron-pair acceptor; powerful bases; alkalis; caustic bases; highly basic compounds; Lewis base; electron-pair donor.

Additional scientific description

Both acids and bases can cause major public harm. They are both principally corrosive because they catalyse hydrolysis reactions and other nucleophilic substitution reactions that result in the decomposition of biological molecules. (Brown, 2018; Burrows et al., 2021; McMurry, 2004; Wade and Simek, 2022) Acids are chemical species that are capable of donating a proton (Bronsted Acid) or capable of forming a covalent bond with an electron pair (Lewis Acid). (IUPAC, 2014) The dissociation process of strong acids almost goes to completion, meaning almost all of the acid molecules break apart into ions, producing high concentrations of hydronium ions that can initiate undesirable chemical reactions. This characteristic is in contrast to weak acids, which only partially dissociate in water. (Wade and Simek, 2022) Examples of strong acids include hydrochloric acid, nitric acid (ICSC 0183, 2016), perchloric acid (ICSC 1006, 2000) and sulphuric acid (ICSC 0362, 2016).

Bases are chemical species that have an available pair of electrons capable of forming a covalent bond with a proton (Brønsted base) or with the vacant orbital of some other species (Lewis base). (IUPAC, 2014) The dissociation process of strong bases goes to completion, producing high concentrations of hydroxide ions. They have a high affinity for accepting protons which fully neutralises them. The strength of the base is measured by its ability to donate hydroxide ions in solution. Lewis theory defines a strong base as an electron pair donor, making them effective at forming bonds with electron-deficient species. (Atkins & Jones, 2010; Burrows et al.,2021; McMurry et al., 2004; Wade and Simek, 2022) Examples of strong bases include caesium hydroxide (ICSC 1592, 2006), calcium hydroxide (ICSC 0408, 1997), lithium hydroxide (ICSC 0913, 2009), potassium hydroxide (ICSC 0357, 2010) and sodium hydroxide (ICSC 0360, 2010).

Lewis acids are electron-pair acceptors that are able to react with a Lewis acid base to form a Lewis adduct, by sharing the electron pair donated by the Lewis base. (IUPAC, 2014)

$$Lewis\ Acid + Lewis\ Base \rightarrow Lewis\ Adduct$$

Acids and bases can form conjugate acid-base pairs, where the acid formed on protonation of a base is called the conjugate acid, and the base is the conjugate base. The conjugate acid always carries one unit of positive charge more than the base, but the absolute charges of the species are immaterial to the definition. (IUPAC, 2014h) Strong acid-base reactions are typically exothermic - the new bond formed between the proton and the base is stronger than the bond that was broken to release the proton, therefore, the released energy raises the temperature of the surroundings. The strength of an acid is inversely proportional to the strength of its conjugate base - i.e. the conjugate base of a strong acid must be a weak base; and the conjugate base of a weak acid must be a strong base. In the reaction of an acid with a base, the equilibrium generally favours the weaker acid and base. (Wade and Simek, 2022)

Metrics and numeric limits (Brown et al., 2018; IUPAC, 2014; McMurry et al., 2004)

Metrics are used to quantify the strength of acids, including their pH, pOH, pK_a, and pK_b; acidity/ionisation constants (K_a, K_b, and K_w); degree of dissociations; and concentrations. pH (equation 1) is a measure of how acidic or alkaline a substance is, ranging (for aqueous solutions) from 0 (strongly acidic) to 14 (strongly basic).

$$pH + pOH = 14 \qquad \textbf{Equation 1}$$

Strong acids have high concentrations of hydronium ions, typically giving low pH values close to zero when fully dissociated in water. The pK_a (equation 2) is a measure of the concentration of hydrogen ions when there are equal concentrations of both the ionised and unionised form of a substance. Strong acids also tend to have pK_a values below zero due to their equilibrium lying to the far right, resulting in negligible concentrations of undissociated acid. Whereas strong bases have high concentrations of hydroxide ions, typically giving high pH values close to 14 when fully dissociated in water. The pOH is a measure of the concentration of hydroxide ions in a solution. Strong bases also tend to have pOH values close to zero.

$$pK_a + pK_b = pK_w \qquad \textbf{Equation 2}$$

The acidity constant (K_a equation 3) is another equilibrium constant for splitting off a proton from a charged or uncharged acid. This metric is usually very high for a strong acid, indicating complete dissociation. (IUPAC, 2014) Due to this dissociation, the concentrations are also typically very high.

$$K_a K_b = K_w \qquad \textbf{Equation 3}$$

The ionisation constant is another equilibrium constant for quantifying the extent to which a base ionises in solution. This metric is usually very large for a strong base, indicating complete ionisation. The degree of dissociation is how much the strong base completely dissociates into ions when dissolved in water, producing hydroxide ions. Acids can be neutralised by strong bases, producing water and salt during the vigorous reaction. This is due to the high concentration of hydroxide ions, giving an overall high concentration for a strong base.

Key relevant UN convention / multilateral treaty

Occupational Safety and Health Administration (OSHA), Chemical Hazards and Toxic Substances: Controlling Exposure. (OSHA, 2024)

European Union (EUR), The Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) Regulation. (EUR-Lex, 2023)

United Nations Environment Programme (UNEP), Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (UNEP, 2011).

United Nations Environment Programme (UNEP), Rotterdam Convention on the Prior Informed Consent (PIC) Procedure for

Preliminary – Corrections Pending

Certain Hazardous Chemicals and Pesticides in International Trade (UNEP, 2010).

United Nations Environment Programme (UNEP), Stockholm Convention on Persistent Organic Pollutants (POPs) (UNEP, 2019).

Organisation for the Prohibition of Chemical Weapons (OPCW), Chemical Weapons Convention (OPCW, 2024a, b).

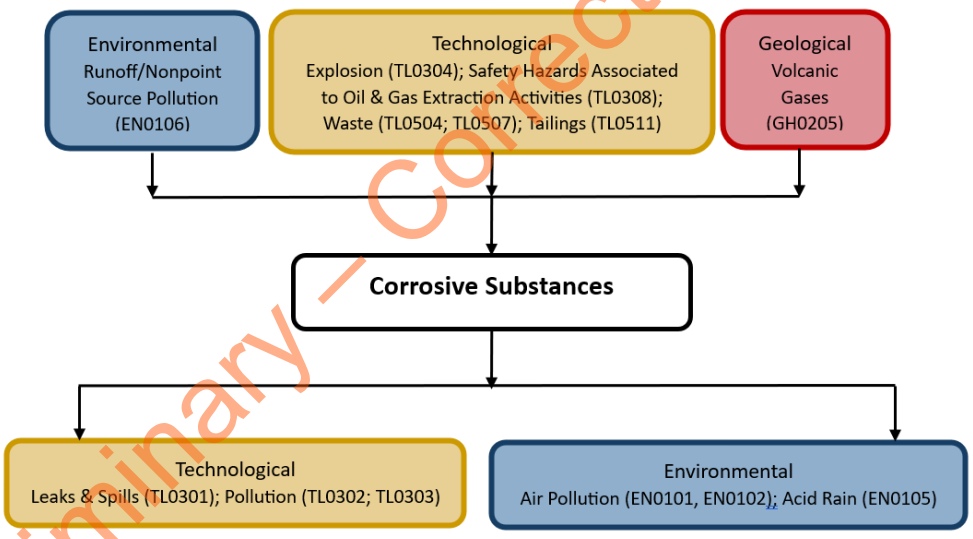
United Nations Environment Programme (UNEP), Montreal Protocol on Substances that Deplete the Ozone Layer (UNEP, 2020)

Examples of hazard drivers, impacts and risk management

Hazard Drivers of corrosive substances, such as strong acids and bases, largely result from their widespread use in industry, as well as in laboratories, for chemical manufacture and synthesis. Industrial processes often use large amounts of acids or bases, such as sulphuric acid, sodium hydroxide and potassium hydroxide, which can lead to hazardous situations. Strong bases are also used in water treatment processes to adjust pH levels and neutralise acidic wastes.

Impacts of strong acids include improper disposal or accidental release, which can lead to soil and water contamination, harming aquatic life and ecosystems, as well as acid rain (HIP MH0033), which is primarily caused by sulphuric and nitric acids - release of sulphur and nitrogen oxides can also lead to air pollution (HIP MH0018; HIP EN0001; HIP EN0002). (EPA, 2024) Acid rain (HIP MH0033) can lead to the corrosion of metals and infrastructure, resulting in leaks, structural failures, and costly repairs. Other impacts include human health risks - coming into contact with strong acids and bases can cause severe chemical burns, skin irritation, eye damage, and respiratory issues. Inhalation of strong acid or strong base vapours can lead to respiratory problems. (NIH, 2022)

Multi-hazard Context: The figure below summarises common interactions between strong acids & strong bases and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring strong acids & strong bases. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Regulatory agencies, health and safety agencies, fire services and manufacturers of chemicals provide material safety data sheets
How is the Hazard Observed/Monitored/Forecast	Sensors, monitoring and alarm systems, preventative maintenance and inspection

Risk Management: strategies include implementing strict safety protocols, providing adequate personal protective equipment (PPE), and conducting thorough employee training on the safe handling and storage of strong acids. (OSHA, 2024) Examples of safety implementations include installing fume hoods, ventilation systems, and acid-resistant materials that can minimise exposure and prevent accidental releases. Ensuring the proper disposal of chemicals through the treatment and disposal methods that minimise environmental impact. Adhering to regulatory requirements and industry standards can also mitigate risks. Further

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risk management strategies include developing comprehensive emergency response plans, including procedures for spill containment, evacuation, and medical treatment. (NFPA, 2020) In the case of a disaster, using spill kits and flushing the strong acids with plenty of water is advised.

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Coordinating agency or organisation

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0902 / CHEMICAL / Other Chemical Hazards

Ammonium Nitrate

Definition

Ammonium nitrate (NH_4NO_3) is principally used as a high-nitrogen content fertilizer in agricultural applications. It is also a major component of industrial explosives, and similar mixtures have been used as improvised explosive devices. Thousands of people have been killed in accidental ammonium nitrate explosions triggered either by a shock/explosion or by fire spreading into a storage facility. Overuse as a fertilizer can lead to contamination of drinking water.

References

UNECE 2009 Recommendations on the Transport of Dangerous Goods, Model Regulations, Sixteenth edition, United Nations, ISBN` 978-92-1-139136-7 (Recommendations on the Transport of Dangerous Goods, Model Regulations | UNECE)

UK Legislation 2003 (The Ammonium Nitrate Materials (High Nitrogen Content) Safety Regulations 2003 (legislation.gov.uk))

IMO, International Maritime Dangerous Goods Code (IMDG), two volumes. IMO Publications, London (The International Maritime Dangerous Goods (IMDG) Code (imo.org))

Annotations

GHS Classification (UNECE, 2023)

Synonyms

NH_4NO_3, nitrate of ammonia, ammonium saltpetre, Norway saltpetre, AN, ammonium salt of nitric acid

Additional scientific description

Ammonium nitrate is a highly reactive material. Its principal use is as a high-nitrogen content fertiliser, but it is also used in rocket propellants and other explosives. The principal acute hazard is explosive, but overuse in agriculture can lead to contamination of water supplies and contribute to eutrophication. When heated or involved in a fire, ammonium nitrate can decompose, releasing toxic gases including nitrogen oxides and ammonia. It can melt and potentially explode if the molten mass becomes confined. Ammonium nitrate also falls into HSNO Hazard Class 5.1 – oxidising agents. Contact with combustible materials, particularly flammable liquids (HSNO Hazard Class 3 materials) or flammable or reactive solids (HSNO Hazard Class 4) will generate potentially explosive mixtures that may detonate on exposure to even minimal mechanical shocks or mild heating. Mixtures of ammonium nitrate and fuel oil (or other hydrocarbon sources) have been used as improvised explosive devices on both small and large scales (e.g. Oklahoma City bombing). Ammonium nitrate is a strong oxidizer that can accelerate burning when involved in a fire and cause combustible materials (e.g., wood, paper, oil) to ignite, even in the absence of air. The International Labour

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Organisation provides a safety card for the pure compound and notes the shock sensitivity when contaminated with organic material (ILO, no date).

Metrics and numeric limits

Many jurisdictions regulate storage facilities and limit quantities based on conditions due to the potential for accidental detonation. For example, the UK Health and Safety Executive specifies that amounts greater than 150 tons must be notified to the local Fire and Rescue Service (UK HSE, No Date). Detonation resistance tests are sometimes employed (UNECE 2009, UK Legislation 2003)

Key relevant UN convention/multilateral treaty

UNECE Industrial Accidents Convention Industrial accidents | UNECE

Examples of hazard drivers, impacts and risk management

Hazard Drivers Ammonium nitrate is essential and used in large amounts as a fertiliser in maintaining agricultural production to feed increasing populations. In its pure form (>98%), ammonium nitrate is still an explosive, but it is much less sensitive than when mixed with oxidisable fuels. Examples have been reported where bombs or shells have exploded in ammonium nitrate stockpiles and succeeded only in spreading it, but there are also examples where the stockpile has exploded in such circumstances. Ammonium nitrate may be relatively insensitive, but it is also unpredictable. Detonation resistance tests are sometimes employed to assess the explosive tendencies of particular batches of material.

The risk of explosion increases significantly when the material is heated to melting (mp 169ºC), particularly if the liquid is in a confined space. Fire, therefore, presents a particular risk of explosion. Impurities such as chloride salts or heavy metals have been associated with higher risks of explosion, as has low pH (i.e. more acidic conditions) or the presence of high pressures. The sensitivity to detonation also varies with the particle size, with fine powders or porous solids exhibiting higher propensity to explode than larger, more dense particles. The high reactivity of fine powders is likely due to the high surface area (more area at which chemical reaction can occur), while that of the porous solids may be due to both higher surface areas and the ability to absorb contaminants such as those mentioned above. Most ammonium nitrate that is to be used in fertiliser applications is formulated in the denser prill form (small spheres) or granules, but fine powders will inevitably be produced through mechanical action as the material is handled after production.

Impacts: Fires that impact ammonium nitrate transport or storage facilities can trigger explosions (e.g. Oppau, Germany, 1921; Texas City, USA, 1947; Toulouse, France, 2001; Neyshabur, Iran, 2004; Beirut, Lebanon, 2020).

Products from complete reaction of ammonium nitrate during an explosion are dinitrogen (N_2), dioxygen (O_2), and water (H_2O). The high bond energies (946 kJ/mol, 497 kJ/mol, and 926 kJ/mol respectively) of these stable molecules mean that a great deal of energy is released when they are formed, and this contributes to the explosive properties of the compound. The large number of molecules that are produced through the chemical reactions during the explosion contributes to the large forces and blast waves associated with such explosions. The presence of fuel oil or other materials, such as powdered metal, allows further reactions to occur that generate even more energy and more gaseous products (e.g. carbon dioxide, CO_2) that will increase the explosive effect. The explosion may release toxic chemicals (resulting from an incomplete reaction) and spread unreacted ammonium nitrate, contaminating the environment (Rehman 2021).

If it does not explode, ammonium nitrate will decompose on heating to generate toxic nitrogen oxide gases (NOx).

Nitrate run-off from (over-) fertilised pastures can contaminate aquifers and drinking water supplies.

Multi-hazard Context: The figure below summarises common interactions between ammonium nitrate and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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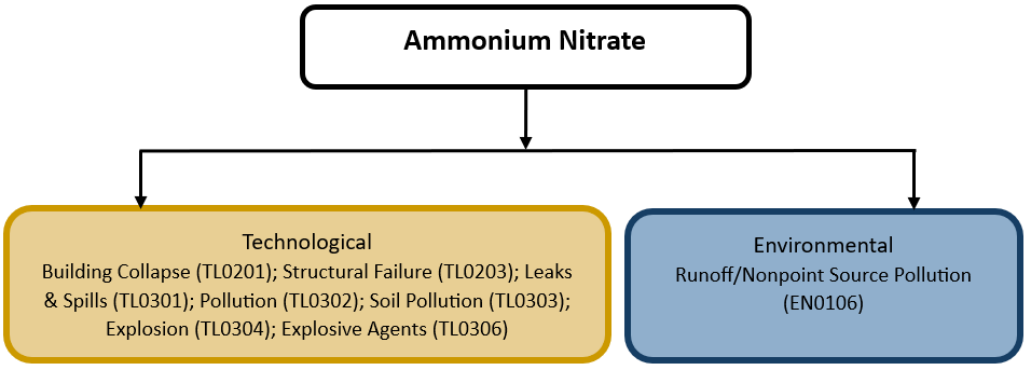

Monitoring: The section and the table below offer an overview of monitoring ammonium nitrate. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	UNECE 2009 Recommendations on the Transport of Dangerous Goods UK Legislation 2003 ILO No Date ICSC 0216 - AMMONIUM NITRATE (ilo.org) IMO, International Maritime Dangerous Goods Code (IMDG)
How is the Hazard Observed/Monitored/Forecast?	Regular inspections as part of risk management may provide some elemen early warning, but the nature of these events makes early warning very dif

Risk Management: The principal hazards of storage of ammonium nitrate are associated with the propensity for explosion, either through direct detonation or detonation as a result of heating and/or melting (possibly as a result of a fire). There are also significant risks associated with contamination and leakage. Contamination with combustible materials through spillage on packaging or other contact can produce materials that are much more sensitive and may detonate on either mild mechanical shocks or minimal heating. Should this occur on even a small scale, it may be sufficient to detonate the surrounding bulk material. Leakage of ammonium nitrate from bags or other containment can result in caking of material on the warehouse floor and an increased risk of contamination with spilled oil (e.g. from forklifts, trucks or other vehicles) and consequent explosion. Sparks from electrical equipment or build-up of static electricity are more likely to initiate an explosion if finely powdered ammonium nitrate is present as a result of leakage from bags. Such powder will almost certainly be present even if the bulk material is made up of prills or granules.

The scale of the hazard will depend on the quantity of the material present, as a large amount of material increases the likelihood of leakage. Furthermore, a large quantity has the potential to generate a very large explosion, whereas a small amount of material will have a correspondingly smaller effect. There are numerous examples of explosions occurring during the transport or storage of ammonium nitrate. In many cases, these have occurred as a result of fires, particularly in enclosed places such as holds of cargo vessels. Some of them have been very large and killed hundreds (e.g. Oppau, Germany, 1921; Texas City, USA, 1947; Toulouse, France, 2001; Neyshabur, Iran, 2004; Beirut, Lebanon, 2020).

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Preliminary – Corrections Pending

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Coordinating agency or organisation

UNECE United Nations Economic Commission for Europe (UNECE)

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0903 / CHEMICAL / Other Chemical Hazards

Chemical Warfare Agents

Definition

Chemical agents or 'chemical warfare agents' (chemical weapons) are chemicals, including dual-use chemicals, used to cause intentional death or harm through their toxic properties, and are a major public hazard. (OPCW, 2024a, b, c).

References

OPCW, 2024a. What is a chemical weapon? Organisation for the Prohibition of Chemical Weapons (OPCW). www.opcw.org/our-work/what-chemical-weapon Accessed 6 April 2024.

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Annotations

GHS Classification (UNECE, 2023)

Synonyms

Nerve agents; blister agents; choking agents; blood agents; riot control agents

Additional scientific description

Chemical warfare agents represent a significant threat due to their potential for mass casualties and long-term environmental and health impacts. Munitions, devices and other equipment specifically designed to deliver toxic chemicals also fall under the definition of chemical weapons. Dual-use chemicals also classify as chemical warfare agents. These are any chemical that has legitimate peaceful uses, but which may also be used to make chemical weapons, for example, thiodiglycol is an ingredient in pen ink that can also be used as a precursor to mustard agents. Equipment in certain chemical production facilities can even be considered dual use in the sense that it may be converted to produce chemical weapons or their precursors. (OPCW, 2024d) The Chemical Weapons Convention (CWC) prohibits the use of toxic chemicals and their precursors and also covers toxins of

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biological origin; it also covers munitions or devices, and equipment directly in connection with these. The relevant toxic chemicals are listed in the Chemical Weapons Convention's Annex on Chemicals (OPCW, 2024b) and, in principle, the understanding and application of a so-called 'General Purpose' Criterion (GPC) and include (OPCW, 2024a):

- Blistering agents: These toxic compounds act via inhalation and contact, affecting the eyes, respiratory tract, and skin, first as an irritant and then as a cell poison. Exposure to blister agents causes large and often life-threatening skin blisters that resemble severe burns and often results in blindness and permanent damage to the respiratory system. Examples include mustard gas (ICSC 0418, 2005).
- Blood agents: These agents inhibit the ability of cells to transfer and use oxygen, effectively causing the body to suffocate. Blood agents generally enter the body through inhalation and are distributed via the blood. Examples include hydrogen cyanide (ICSC 0492, 2018) and cyanogen chloride (ICSC 1053, 1999).
- Choking agents: Inflicting injury mainly on the respiratory tract, choking agents irritate the nose, throat, and especially the lungs. When inhaled, these agents cause alveoli (air sacs in the lungs) to secrete fluid, essentially drowning those affected. Chlorine (ICSC 0126, 2009) and phosgene gas (ICSC 0007, 2013) are examples.
- Nerve agents: Nerve agents block impulses between nerve cells or across synapses and are highly toxic, with rapid effects. They act primarily by absorption through the lungs and skin, inhibiting the action of critical enzymes required for the normal functioning of the nervous system, causing seizures, loss of body control, muscle paralysis (including heart and diaphragm), and ultimately death. Sarin and VX gas are examples.
- Riot control agents: These agents are utilized to temporarily incapacitate a person by irritating the eyes, mouth, throat, lungs and skin, as well as constricting the airways. They are only considered chemical weapons when used in warfare. States can possess these agents for domestic law enforcement purposes, but if they are a member CWC, they must declare which type of agents they have. Examples include tear gas and pepper spray.

Metrics and numeric limits

The Chemical Weapons Convention (OPCW, 2024b, c) categorizes chemical substances into three schedules based on their potential for use in chemical weapons and their toxicity. Schedule 1 chemicals have no or very limited legitimate uses and have strict controls and verification measures. Schedule 2 chemicals have legitimate uses but can also be used as chemical weapons. Schedule 3 chemicals are precursors used in the production of chemical weapons. Parties to the Chemical Warfare Convention must declare any past or current chemical weapons-related activities and facilities, which are verified by the OPCW.

Whilst the Biological Weapons Convention (UNODA, 2021) does not have specific numerical limits, it prohibits the development, production, acquisition, transfer, and stockpiling of biological agents or toxins for hostile purposes.

Key relevant UN convention / multilateral treaty

Organisation for the Prohibition of Chemical Weapons (OPCW), Chemical Weapons Convention. (OPCW, 2024a,b)

United Nations Office for Disarmament Affairs (UNODA), Biological Weapons Convention. (UNODA, 2021)

United Nations Office for Disarmament Affairs (UNODA), UN Security Council Resolution 1540. (UNODA, 2004)

Examples of hazard drivers, impacts and risk management

Hazard Drivers have been wars and civil wars, associated with death, injury and often life-long disabilities (Australia Group, 2021a, b). Other drivers include political and ideological motivations (instilling fear and intimidating adversaries, or to achieve specific political aims), and technological advancements - advances in chemical synthesis, weaponization and delivery systems can lower barriers to acquiring and deploying chemical weapons, making them more accessible to state and non-state actors.

Control measures include import-export control of relevant chemical agents and precursors (Australia Group, 2021a, b). A key factor in ensuring that toxic chemicals and their precursors are not meant to cause death or other harm (i.e., as a 'method of warfare') is the application of the 'General Purpose' Criterion. A given activity or programme may be for 'defensive' (i.e., permitted) or 'offensive' (i.e., prohibited) purposes.

Impacts of chemical weapons include immediate and long-term health effects, and death, resulting in mass casualties, overwhelming healthcare systems, and causing psychological trauma. The deployment of weapons can also lead to environmental contamination, requiring extensive decontamination efforts and long-term ecological consequences. It can also lead to disruption to economic activities and economic losses, hindering recovery efforts. The use of chemical weapons can also provoke international condemnation, trigger diplomatic crises, and lead to military retaliation or sanctions against the responsible parties.

Multi-hazard Context: The figure below summarizes common interactions between chemical warfare agents and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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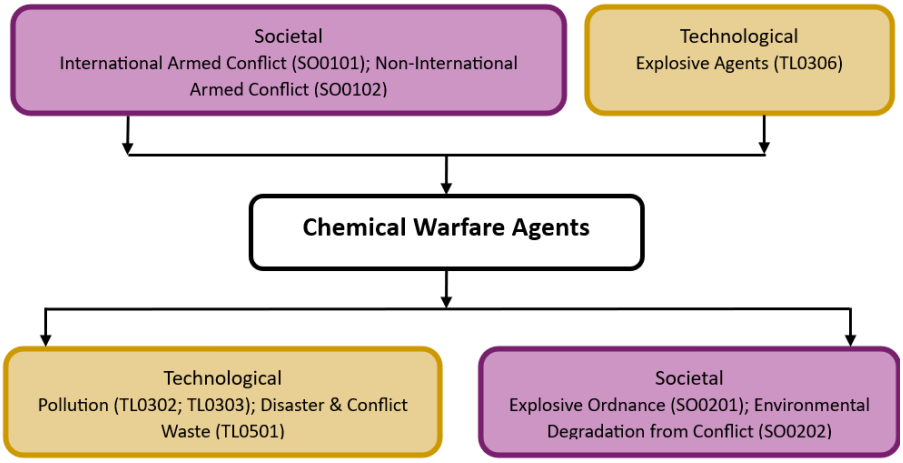

Monitoring: The section and the table below offer an overview of monitoring chemical warfare agents. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Organization for the Prohibition of Chemical Weapons (OPCW); national terrorism agencies
How is the Hazard Observed/Monitored/Forecast?	Sensors; monitoring networks; response protocols

Risk Management strategies include prevention and non-proliferation, by strengthening treaties and verification methods. In addition, an international network of specialized analytical laboratories, able to detect potential chemical warfare agents in the environment and in exposed human bodies, is likely to be of benefit (EU, 2009). New technological approaches are being developed for the detection and monitoring of chemical warfare. Developing and exercising response plans, including medical treatment protocols, decontamination procedures, and public communication strategies, to mitigate the consequences of chemical weapons.

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Coordinating agency or organisation

Organization for the Prohibition of Chemical Weapons (OPCW). International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0100 / CHEMICAL / Heavy Metals and Other Trace Elements

Heavy Metals and Other Trace Elements

Definition

Heavy metals are metallic trace elements with either high relative atomic weights or occurring in materials with high densities. Trace Elements is the term used for elements that are generally found in soil at low concentrations but can still have significant impacts on human health and ecosystems when their levels exceed safe limits, as in the case of many heavy metals. Trace element contaminants that have biological significance are generally found in soil at concentrations of less than 100 mg/kg, and sometimes in aquatic ecosystems or as particulates in the atmosphere. Biological significance would include elements that are essential or toxic to any organism; some elements can be both, depending on their concentration. Many of the trace elements of importance are metals, while others are metalloids, alloys, non-metals, actinoids, and halogens occurring in a variety of chemical states (elemental, cations, anions, oxyanions, methylated, etc.). This category can overlap or be used synonymously with terms such as potentially toxic elements, heavy metals, persistent inorganic contaminants, inorganic contaminants, and halides, such as fluoride and iodide. For the clarity of this document, the term trace elements will be used (FAO and UNEP, 2021a).

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Reference

FAO and UNEP. 2021a. Global Assessment of Soil Pollution. Report. Rome, FAO. https://doi.org/10.4060/cb4894en Accessed 20 July 2024

Annotations

GHS classification

Synonyms

Heavy metals, Metallic elements, Metallic compounds, Alloys, Halogens, Halides, Metalloids, Metallic components, Inorganic contaminants, Potential Toxic elements, Persistent Inorganic Contaminants (PIP), Potentially Toxic Elements (PTE), Inorganic contaminants.

Additional scientific description

Trace elements can become contaminants when their concentrations significantly exceed natural levels due to anthropogenic activities, such as industrial processes, mining, agriculture, and waste disposal. These contaminants can accumulate in soil, water, and biota, potentially causing adverse effects on ecosystems and human health.

- **Essential Trace Elements**: These are elements required in small amounts for normal physiological functions. Examples include iron (Fe), zinc (Zn), copper (Cu), and selenium (Se).
- **Non-Essential or Toxic Trace Elements**: These are elements that can be toxic to organisms even at low concentrations. See other Hazard Information Profiles for examples, which include lead (Pb, CH0103), mercury (Hg, CH0104), cadmium (Cd, CH0102), and arsenic (As, CH0101).
- **Metals:** The term "metal health hazard" refers to the potential risks posed to human health by exposure to metallic substances. Metals are naturally occurring elements that are found in various forms in the environment, and while many metals are essential for life and have beneficial uses, some can be harmful when encountered in certain forms or concentrations. Health hazards associated with metals can result from exposure through inhalation, ingestion, or skin contact, depending on factors such as the specific metal involved, its chemical form, and the duration and intensity of exposure. Some common occurrences of metals: Ores, Mineral Deposits, Soil and Sediments, Water Bodies, Vegetation, Atmosphere, Manufactured Products, Waste and Recycling.
- **Metalloids:** elements that exhibit some metal and some non-metal properties.
- **Alloys:** Metals can be combined with other elements to form alloys, which often exhibit properties superior to those of the individual elements. Common alloys include brass (copper and zinc), bronze (copper and tin), stainless steel (iron, chromium, and nickel), and aluminum alloys.
- **Non-Metal Contaminants:** elements or ions that have the potential to be contaminants in soil and water. Because of their high ionic potential, non-metals of Groups 13 to 16 of the Periodic Table in their normal oxidation states form oxyanions.
- **Halides**, the anions from Group 17 such as fluoride, chloride, bromide, and iodide are considered additionally as phytotoxic air pollutants and can have a severe impact on health at high concentrations. High bromide concentrations can have lethal effects on aquatic organisms. In addition, halides are scavengers of hydroxyl radical during advanced oxidation processes, reducing efficiency of several water treatment efforts.

Unlike organic contaminants, which can be degraded when metabolized by different organisms, trace elements cannot be degraded by metabolic processes. However, an essential peculiarity of trace elements is the potential to exist as different species (e.g. different oxidation states as in chromium III/chromium VI or arsenic III / arsenic V) and the tendency to form bioavailable metal-organic compounds (e.g. methylmercury or tetramethyl-lead), which effectively determines the bioavailability and toxicity. In practice, most assessments of trace elements measure and report total concentrations (e.g. of chromium) rather than the specific chemical form of the element (e.g. chromium III or chromium VI) due to the complexity of analyses and interpretation of sequential extraction methods in laboratories.

Fluoride, a non-metal contaminant, is a naturally occurring mineral to which the public is often exposed via drinking water. Depending on the dose intake, fluoride may have both beneficial effects (reducing the incidence of dental caries) and negative effects (causing tooth enamel and skeletal fluorosis following prolonged high exposure) (adapted from NCBI, 2020 and WHO, no date), see CH0105.

Iodide contamination poses significant health risks, including thyroid dysfunction and increased cancer risk, particularly from radioactive isotopes like iodine-131. Environmental impacts include disruption of aquatic ecosystems and soil quality degradation. Effective monitoring and management strategies are essential to mitigate these risks and protect both public health and the environment, see CH0105.

Metrics and numeric limits

Guidance values are complex, but in summary, the following may be helpful:

- **Arsenic**: Limits range from 10 µg/L in drinking-water to 0.39 mg/kg in residential soil.
- **Cadmium**: Limits range from 3-5 µg/L in drinking-water to 0.43 mg/kg in residential soil.

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- **Lead**: Limits are typically around 10-15 µg/L in drinking-water and 400 mg/kg in soil.
- **Mercury**: Limits range from 1-6 µg/L in drinking-water to 1.3 mg/kg in residential soil.
- **Chromium**: Limits range from 50-100 µg/L in drinking-water to 0.3 mg/kg for Cr(VI) in residential soil.
- **Fluoride:** The guideline value for fluoride in drinking-water is 1.5 mg/l. In air: the guideline value is 1 µg/m3.
- **Iodide:** The Tolerable Upper Intake Level (UL) for iodine intake for adults is 1,100 micrograms per day. Permissible Exposure Limit, according to OSHA, for iodine in the workplace is 0.1 parts per million. Iodine-131 (a radioactive isotope of iodine) in drinking-water with an MCL of 3 picocuries per liter (pCi/L).

Key relevant UN convention / multilateral treaty

- Basel Convention: Controls transboundary movement of hazardous wastes, including trace elements.
- Rotterdam Convention: Implements prior informed consent for hazardous chemicals, including certain trace elements.
- Stockholm Convention: Focuses on persistent pollutants, including some trace elements.
- Minamata Convention: Specifically targets mercury, a key trace element.
- CLRTAP: Addresses air pollution, including heavy metals like lead, cadmium, and mercury.

Examples of hazard drivers, impacts and risk management

Hazard Drivers of heavy metal/trace element contamination include:

(1) **Industrial Activities;** Example: Mining, quarrying, and smelting of metals can release trace elements such as lead (Pb), cadmium (Cd), and arsenic (As) into the environment.

(2) **Agricultural Practices;** Example: The use of phosphate fertilizers can introduce cadmium (Cd) into soils.

(3) **Urbanization and Infrastructure Development;** Example: Construction activities can lead to increased levels of trace elements such as chromium (Cr) and lead (Pb) from building materials, road construction and waste**.**

(4) Waste Management Practices; Example: Inadequate disposal and treatment of electronic waste and used batteries can release trace elements such as mercury (Hg) and lead (Pb) into the environment.

(5) Climate Change. Example: Increased temperature and precipitation can alter the mobility and bioavailability of trace elements, affecting their distribution and concentration.

(6) Natural Disasters: Example: Flooding can mobilize trace elements from contaminated soils and sediments into water supplies.

Impacts of Heavy Metals and Trace Elements Contamination are:

(1) Environmental Impact; Example: Bioaccumulation of mercury (Hg) in aquatic ecosystems can harm wildlife and disrupt food chains.

(2) Human Health Effects; Example: Chronic exposure to arsenic (As) in drinking-water can lead to skin lesions, cancer, and cardiovascular diseases.

(3) Soil Degradation; Example: Accumulation of cadmium (Cd) in agricultural soils can reduce soil fertility and crop yields.

(4) Economic Impact; Example: Contaminated land may require expensive remediation efforts, affecting property values and development potential.

Multi-hazard Context: The figure below summarises common interactions between heavy metals & trace elements and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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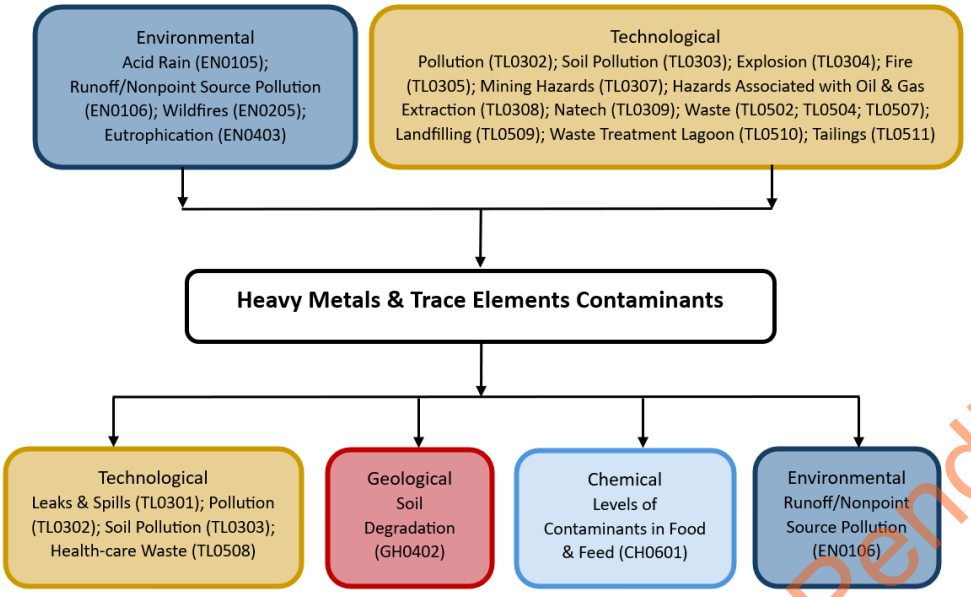

Monitoring: The section and the table below offer an overview of monitoring heavy metals & trace elements. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Water Agencies, Health Agencies, Environmental Agencies, Food & Agriculture Agencies
How is the Hazard Observed/Monitored/Forecast?	Monitoring Technologies can be used to detect heavy metals and trace element levels in water, soil an both in staggered and in real-time; Fixed and portable sensors, such as ion-selective electrodes and spectrophotometers, could provide accurate and continuous measurements for data analysis. Data fro these sensors is collected and analyzed through automated systems, which trigger immediate alerts wh contamination levels exceed the safe threshold.

Risk Management Strategies include:

(1) Regulation and Legislation; Example: The European Union's REACH (Registration, Evaluation, Authorisation, and Restriction of Chemicals) regulation controls the use of hazardous substances, including trace elements.

(2) Pollution Prevention and Control; Example: Implementing best practices in industrial processes to minimize emissions of trace elements.

(3) Environmental Monitoring and Assessment; Example: Regular monitoring of soil, water, and air to detect and quantify trace element contamination.

(4) Remediation and Cleanup; Example: Using phytoremediation to clean up soils contaminated with heavy metals such as cadmium (Cd) and lead (Pb).

(5) Public Awareness and Education; Example: Educating communities about the risks of trace elements and promoting safe practices.

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Coordinating agency or organisation

World Health Organization (WHO), Food and Agriculture Organization of the United Nations (FAO), International Union of Pure and Applied Chemistry (IUPAC)

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CH0101 / CHEMICAL / Heavy Metals and Trace Elements

Arsenic

Definition

Arsenic is a toxic metalloid widely distributed throughout the Earth's crust, generally as arsenic sulphide or as metal arsenates and arsenides. Human exposure to arsenic compounds represents a major public health concern as it has been associated with a range of acute and long-term adverse health effects and diseases (WHO, 2019).

Reference

WHO, 2019. Preventing Disease through Healthy Environments – Exposure to arsenic: A major public health concern. World Health Organization (WHO). apps.who.int/iris/bitstream/handle/10665/329482/WHO-CED-PHE-EPE-19.4.1-eng.pdf?ua=1 Accessed 19 July 2024.

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Annotations

GHS Classification (UNECE, 2023)

Synonyms

As, White arsenic, Arsenious acid, and Fowler's solution.

Additional scientific description

Arsenic (chemical symbol As, atomic number 33) can be released into the atmosphere and water in the following ways: natural activities, such as volcanic activity, dissolution or desorption of minerals (particularly into groundwater), exudates from vegetation and wind-blown dusts; human activities, such as metal smelting, combustion of fossil fuels (especially coal), mining, timber treatment with preservatives and, historically, agricultural pesticide production and use; remobilisation of historic sources, such as mine drainage water; and mobilisation into drinking-water from geological deposits by drilling of tube wells (WHO, 2019). Arsenic compounds have been used as chemical weapons (OPCW, 2024)

In water, arsenic occurs in one of two main forms: arsenite As(III) under reducing conditions and arsenate As(V) if the water is oxygenated. It can be released to the atmosphere, primarily as the trioxide, mainly by high-temperature processes or through volatilisation from aerated soils. In the atmosphere, it is mainly adsorbed onto particles, which are dispersed by winds and deposited on land and water (WHO, 2019).

Soluble inorganic arsenic is highly acutely toxic. Intake of inorganic arsenic over a long period can lead to chronic arsenic poisoning (arsenicosis). Effects, which can take years to develop depending on the level of exposure, include skin lesions, peripheral neuropathy, gastrointestinal symptoms, diabetes, cardiovascular disease, developmental toxicity, and cancer of the skin and internal organs (IARC, 2018). Organic arsenic compounds, which are abundant in seafood, are less harmful to health and are rapidly eliminated by the body.

Human exposure to arsenic and arsenic compounds can occur through environmental or occupational routes. Human

exposure to elevated levels of inorganic arsenic occurs mainly through the intake of groundwater containing naturally high levels of inorganic arsenic, food prepared with this water, and food crops irrigated with high-arsenic water sources. Public health actions need to be continued to reduce human exposure to arsenic, particularly in areas with naturally high levels in groundwater (WHO, 2019).

Metrics and numeric limits

In 2002, the World Health Organization (WHO) reported that at least 140 million people in 50 countries were estimated to have been drinking water containing arsenic at levels above the WHO provisional guideline value of 10 µg/L (WHO, 2019). Inorganic arsenic is naturally present at high levels in the groundwater of several countries, such as Argentina, Chile, China, India (West Bengal), Mexico, the USA, and particularly Bangladesh, where it was estimated that in 2012 approximately 19 million people were exposed to drinking-water concentrations above the national standard of 50 µg/L and 39 million people were drinking water with levels of arsenic above 10 µg/L. In 2010, 21.4% of all deaths in a highly affected area of Bangladesh were attributed to arsenic levels of above 10 µg/L in drinking-water, while another analysis published in 2012 for all districts indicated an annual total of nearly 43,000 deaths (about 5.6% of all deaths) attributable to chronic arsenic exposure (WHO, 2019).

The WHO has published arsenic guidelines for tolerable intake levels, drinking-water and air (WHO, 2019):

- Tolerable daily intake level: In a review of the latest scientific evidence conducted in 2010, the Joint Food and Agriculture Organization of the United Nations (FAO)/WHO Expert Committee on Food Additives (JECFA) determined the lower limit on the benchmark dose for a 0.5% increased incidence of lung cancer (BMDL0.5) from epidemiological data to be 3.0 µg/kg body weight per day (2–7 µg/kg body weight per day based on the range of estimated total dietary exposure). No new tolerable intake level could be established. In areas where levels in water are below the WHO drinking-water guideline value, human health effects are unlikely.
- Drinking-water: The provisional guideline value is 10 µg/L, in light of practical difficulties in removing arsenic in drinking-water, every effort should be made to keep concentrations as low as reasonably possible and below the guideline value when resources are available.
- Air: A safe level of arsenic in air cannot be established.

Key relevant UN convention / multilateral treaty

International Labour Organization C042 - Workmen's Compensation (Occupational Diseases) Convention (Revised), 1934 (ILO, 1934).

Examples of hazard drivers, outcomes and risk management

Hazard Drivers: Drinking-water poses the greatest threat to public health from arsenic (WHO, 2019). Exposure of smokers to arsenic arises from the natural inorganic arsenic content of tobacco. Exposures were higher in the past when tobacco plants were treated with lead arsenate insecticide (WHO, 2019).

Impacts: Most arsenic in industrial processes is used to produce antifungal wood preservatives, which can lead to soil contamination. Other current or historical uses occur within the pharmaceutical and glass industries, in the manufacture of alloys, sheep dips, leather preservatives, arsenic-containing pigments, antifouling paints and poison baits and, to a diminishing extent, in the production of agrochemicals (especially for use in orchards and vineyards). Arsenic compounds are also employed in limited amounts in the microelectronics and optical industries. High arsenic levels in air can be found in the working environment as well as the general environment around non-ferrous metal smelters, where arsenic trioxide may be formed, and some coal-fired power plants (especially those using low-grade brown coal) (WHO, 2019).

In areas where arsenic is not naturally present at high levels, food usually contributes most to the daily intake of arsenic. Fish, shellfish, meat, poultry, dairy products and cereals are the main sources of dietary intake. However, the arsenic in fish and shellfish is usually in the form of organic compounds (e.g., arsenobetaine) that are of low toxicity. In areas where arsenic is naturally present at high levels, food (e.g., rice) prepared with high arsenic-containing water and food crops irrigated with contaminated water also contribute to total daily intake (WHO, 2019).

Accidents involving arsenic have occurred in various contexts, with significant impacts on human health and the environment.

High concentrations of naturally occurring arsenic poisoning in drinking water have resulted in multiple poisoning episodes worldwide. An example from the 1950's and 1960's was the Taiwan Arsenic Poisoning (Blackfoot Disease), which led to the development of a condition known as Blackfoot Disease, characterized by peripheral vascular disease and gangrene. The contamination was traced to artesian well water with high levels of arsenic (Lai, 1994). A second example is the Bangladesh Arsenic Crisis in the 1990s, where a widespread contamination of arsenic from shallow tube wells led to millions being exposed to high levels of arsenic in drinking water and caused various health issues, including skin lesions, cancers (such as skin, lung, and bladder cancer), cardiovascular diseases, and neurological disorders (Smith, 2000).

Chemical spills have had a negative impact on the environment. An example is the Sandoz Chemical Spill which occurred in

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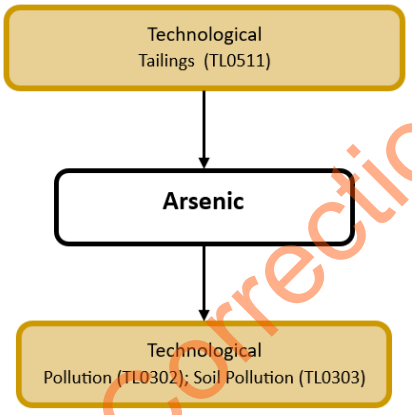
1986. A fire at a Sandoz chemical warehouse in Basel, Switzerland, led to the release of various toxic chemicals, including arsenic compounds, into the Rhine River. The contamination caused widespread fish kills and had significant ecological impacts on the river ecosystem (Capel, 1988).

The historical use of lead arsenate as a pesticide in agriculture led to soil contamination in many regions. Accidental ingestion or inhalation of soil particles containing lead and arsenic residues, particularly by farm workers and children living in treated areas, has resulted in cases of acute poisoning and long-term health effects (Lasky, 1985). The health of inhabitants of communities near mining activities can be affected by arsenic presence. In a region of Colombia where gold mining activities are developed, genotoxicity and mutagenicity in the blood and drinking water of the exposed population were induced by arsenic. The results showed DNA damage related to arsenic in blood ($p < 0.05$) in the exposed population, with arsenic levels above the Agency for Toxic Substances and Disease Registry (ATSDR) limit of 1 µg/L. Mutagenic activity was detected in the drinking water, with only one sample exceeding the WHO's maximum permissible arsenic concentration of 10 µg/L (Calao-Ramos, 2023).

Multi-hazard Context: The figure below summarises common interactions between arsenic and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring arsenic. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	World Health Organization (WHO)
How is the Hazard Observed/Monitored/Forecast?	Sensors and sampling stations to measure arsenic levels in air, water, and soil, coupled with data analysis and modelling to identify contamination trends and predict future risks.

Risk Management: Long-term actions are required to reduce exposure to arsenic from mining, metal smelting and refining, combustion of low-grade coal, pesticide use and timber treatment. In particular, action is needed to reduce the intake of arsenic from drinking-water and food in areas with naturally high levels in the groundwater (WHO, 2019).

The WHO factsheet on preventing disease through healthy environments (WHO, 2019) includes the following risk mitigation recommendations:

- Make available drinking-water with arsenic concentrations below the WHO provisional drinking-water guideline value of 10 µg/L in areas where the level is higher. Possible measures include:
  - Testing water for arsenic levels and informing users of the results.
  - Installing arsenic removal systems, either centralised or domestic, and ensuring appropriate disposal of the removed arsenic.
  - Substituting high-arsenic sources, such as groundwater, with low-arsenic, microbiologically safe sources such as rainwater and treated surface water. Low-arsenic water can be used for drinking, cooking and irrigation purposes, whereas high-arsenic water can be used for other purposes such as bathing and washing clothes.
  - Discriminating between high-arsenic and low-arsenic sources by testing water for arsenic levels and painting tube wells or hand pumps different colours (e.g., red and green).
  - Blending low-arsenic water with higher-arsenic water to achieve an acceptable arsenic concentration level.

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- Reduce occupational exposure to arsenic and its compounds.
- Make both the general public and the health sector aware of the harmful effects of high-arsenic intake and the sources of exposure (including use of high-arsenic water for crop irrigation or food preparation) and how to avoid these sources.
- Monitor high-risk populations for early signs of arsenic poisoning, usually skin problems. It should be noted that total urinary arsenic does not differentiate between inorganic arsenic, which is toxic, and organic arsenic, some of which is not. Where possible, arsenic speciation should be attempted in order to differentiate these two forms (and their metabolites).
- The WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene monitors progress towards global targets on drinking water. In addition, under the new 2030 Agenda for Sustainable Development, the indicator of 'safely managed drinking water services' calls for tracking the population accessing drinking water that is free of faecal contamination and priority chemical contaminants, including arsenic (UN Water, no date; Council of Europe, 2021).

The documented accidents in the impacts section underscore the importance of monitoring and regulating arsenic exposure, implementing safe drinking water practices, and promoting alternative agricultural methods to minimize the risks associated with arsenic contamination.

1. World Health Organization (WHO)
    - Arsenic in Drinking Water: Guidelines and information on the health impacts of arsenic exposure and strategies for prevention.
2. United States Geological Survey (USGS)
    - Arsenic in Groundwater: Information and resources on monitoring arsenic levels in groundwater and surface water across the United States.
    - USGS Arsenic in Groundwater
3. Directive (EU) 2020/2184 of the European Parliament and of the Council of 16 December 2020 on the quality of water intended for human consumption
4. European Commission, Food, Farming, Fisheries, Arsenic in food

Actions to be taken by affected communities to prevent further arsenic exposure for providing safe water for drinking, food preparation, and crop irrigation include:

- Replace high-arsenic sources, like groundwater, with low-arsenic sources, such as rainwater and treated surface water. Use low-arsenic water for drinking, cooking, and irrigation, and high-arsenic water for bathing and washing clothes.
- Identify high-arsenic and low-arsenic sources. Test the water and mark wells or pumps with different colours to indicate arsenic levels. Educate the community for effective use.
- Mix low-arsenic water with higher-arsenic water to reach safe levels.
- Install arsenic removal systems (centralized or domestic) and ensure proper disposal of removed arsenic. Methods include oxidation, coagulation-precipitation, absorption, ion exchange, and membrane techniques. There are more low-cost and effective options available, though long-term effectiveness needs further evidence.

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Coordinating agency or organisation

World Health Organization (WHO).

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0102 / CHEMICAL / Heavy Metals and Trace Elements

Cadmium

Definition

Cadmium is a toxic heavy metal which is widely distributed in the Earth's crust (soil and rocks), air and water; however, human activity has greatly increased levels in environmental media relevant to population exposure. Human exposure to cadmium represents a major public health concern as it has been associated with a range of acute and long-term adverse health effects and diseases (WHO, 2019).

Reference

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Annotations

GHS Classification (UNECE, 2023)

Synonyms

Cd, Cadmium metal, cadmium salts.

Additional scientific description

Cadmium (chemical symbol Cd, atomic number 48) is an element that exists as a number of compounds due to its combining with other elements, including oxygen to form cadmium oxide, chlorine to form cadmium chloride, or sulfur to form cadmium sulfide and cadmium sulfate. Cadmium oxide and cadmium sulfide are most commonly found in the air, whereas cadmium chloride and cadmium sulfate dissolve in water (UK HSA, 2024).

Cadmium is generally present in the environment at low levels; however, human activity has greatly increased levels in environmental media relevant to population exposure. Cadmium can travel long distances from the source of emission by atmospheric transport. It is readily accumulated in many organisms, notably molluscs and crustaceans. Lower concentrations are found in vegetables, cereals and starchy roots (WHO, 2019). Cadmium compounds can be released to the environment in a number of ways, including:

- Natural activities, such as volcanic activity (both on land and in the deep sea), weathering and erosion, and river transport (WHO, 2019).
- Human activities, such as tobacco smoking, mining, smelting and refining of non-ferrous metals, fossil fuel combustion, incineration of municipal waste (especially cadmium-containing batteries and plastics), use of cadmium-containing

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phosphate fertilisers, and recycling of cadmium-plated steel scrap and electric and electronic waste (WHO, 2019).

- Remobilisation of historic sources, such as the contamination of watercourses by drainage water from metal mines or from waste sites (WHO, 2019).

Cadmium exerts toxic effects on the kidney, the skeletal system and the respiratory system and is classified as a human carcinogen (IARC, 1993). Osteomalacia (softening of the bones) and osteoporosis may occur in those exposed through living or working in cadmium-contaminated areas; for example, in an area of Japan where water and soil were contaminated with cadmium from zinc/lead mines, itai-itai ('ouch-ouch') disease (characterised by osteomalacia, osteoporosis, painful bone fractures and kidney dysfunction) used to be widespread (WHO, 2019).

Human exposure occurs mainly from consumption of contaminated food, active and passive inhalation of tobacco smoke, and inhalation by workers in a range of industries. National, regional and global actions are needed to decrease global environmental cadmium releases and reduce occupational and environmental exposure (WHO, 2019).

Metrics and numeric limits

The World Health Organization (WHO) has published cadmium guidelines for provisional tolerable monthly intake levels, drinking water and air (WHO, 2019).

- Provisional tolerable monthly intake: The Joint Food and Agriculture Organization of the United Nations (FAO)/WHO Expert Committee on Food Additives (JECFA) established a provisional tolerable monthly intake for cadmium in 2010 of 25 µg/kg body weight, based on meta-analysis of epidemiological studies on the relationship between urinary cadmium and beta-2-microglobulin (a marker of renal tubular effects). In light of the long half-life of cadmium in humans, JECFA decided to express the tolerable intake as a monthly value.
- Drinking-water: The guideline for cadmium in drinking-water is 3 µg/L.
- Air: The guideline for cadmium in air is 5 ng/m^3 (annual average).

Key relevant UN convention / multilateral treaty

The UNECE Convention on Long-range Transboundary Air Pollution.Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Cadmium contained in soil and water can be taken up by certain crops and aquatic organisms and accumulate in the food chain. Food constitutes the main environmental source of cadmium for non-smokers (see CH0601 Levels of Contaminants in Food and Feed). Highest cadmium levels are found in the kidney and liver of mammals when fed with cadmium-contaminated feed, and in certain species of oyster, scallop, mussel and crustacean (WHO, 2019).

The tobacco plant naturally accumulates relatively high concentrations of cadmium in its leaves. Thus, smoking tobacco is an important source of exposure and, in the case of heavy smokers, daily intake may exceed that from food. Cigarette smoking can cause significant increases in the concentration of cadmium in the kidney, the main target organ for cadmium toxicity (WHO, 2019).

Inexpensive jewellery, toys and plastics can be significant sources of exposure to cadmium, especially for children; however, many countries have moved to restrict or ban cadmium in such products (WHO, 2019).

In terms of occupational exposure through industrial processes, principal uses are currently in nickel-cadmium batteries, pigments, coatings and plating, as a stabiliser in plastics and other materials (including non-ferrous alloys, semiconductors and photovoltaic devices). The highest potential occupational exposures occur in cadmium production and refining, nickel-cadmium battery manufacture, cadmium pigment manufacture and formulation, cadmium alloy production, mechanical plating, zinc smelting, brazing with silver-cadmium-silver alloy solder and polyvinylchloride compounding (WHO, 2019).

Impacts of cadmium exposure include environmental impacts (soil contamination, particularly near industrial sites; water pollution from leaching; and biodiversity loss); human health impacts (kidney damage from ingestion through food and water; bone damage; respiratory issues; and carcinogenic effects); and economic impacts (agricultural losses from reduced crop yields and quality; and healthcare costs for the human health impacts). Documented accidents involving cadmium have occurred in various industries and settings, leading to significant health and environmental impacts.

One of the most well-known incidents involving cadmium occurred in the Jinzu River basin in Toyama Prefecture, Japan, during the mid-20th century. Widespread mining and industrial activities released cadmium into the river, contaminating rice paddies and water supplies. As a result, residents, particularly women, who consumed cadmium-contaminated rice and water developed severe renal and skeletal abnormalities, known as Itai-Itai Disease.

In the 1910s and 1920s, industrial activities in Toyama Prefecture, Japan, led to the release of cadmium and other heavy

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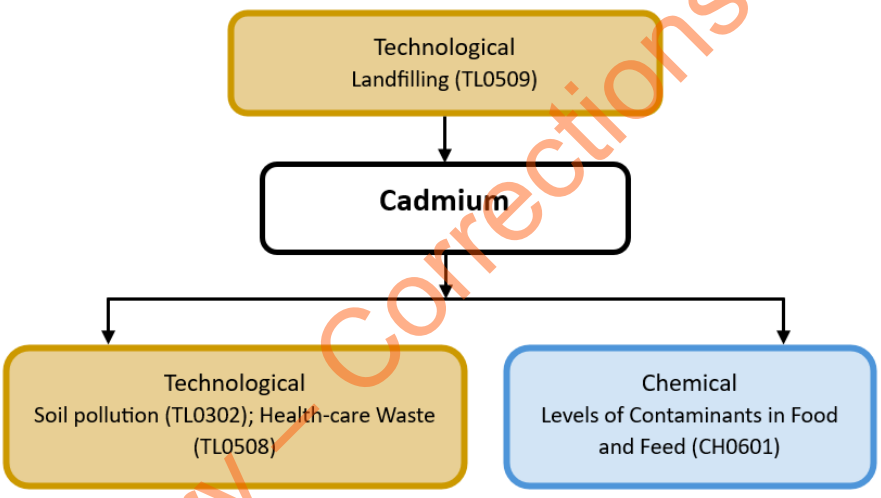
metals into the environment, contaminating soil, water, and crops. This pollution resulted in widespread health problems among residents, including kidney damage and skeletal deformities.

In 2003, in Bangalore, India, the Janaagraha organization discovered lead and cadmium contamination in groundwater sources used by local residents. The contamination was traced to a battery recycling plant in the vicinity. Residents, particularly children, were found to have elevated levels of lead and cadmium in their blood, leading to health concerns and protests against the plant's operations.

Accidental releases of cadmium from industrial facilities, such as metal plating plants, battery manufacturing facilities, and electronic waste recycling operations, have led to localized contamination of air, soil, and water. These incidents can result in acute exposure to cadmium, causing respiratory problems, gastrointestinal issues, and other health effects among workers and nearby residents. (ATSDR, 2012)

These documented accidents underscore the importance of monitoring and regulating cadmium exposure, implementing pollution control measures, and promoting safe handling and disposal practices to prevent adverse health and environmental impacts.

Multi-hazard Context: The figure below summarises common interactions between cadmium and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring cadmium. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	World Health Organization (WHO) Food and Agriculture Organization of the United Nations (FAO).
How is the Hazard Observed/Monitored/Forecast?	Sensors and sampling stations to measure cadmium levels in air, water and soil, coupled with data analysis and modeling to identify contamination trends and predict future risks.

Risk management: The WHO factsheet on preventing disease through healthy environments (WHO, 2019) includes the following risk mitigation recommendations:

- Implement the WHO Framework Convention on Tobacco Control, including providing for protection from exposure to tobacco smoke in indoor workplaces, public transport, indoor public places and, as appropriate, other public places (WHO, 2003).
- Reduce, as far as is practicable, emissions of cadmium – particularly into surface waters – from mining and smelting, waste incineration, application of sewage sludge to the land, and use of phosphate fertilisers and cadmium-containing manure. Develop techniques for the safe disposal of cadmium-containing wastes and effluents.
- Washing fruit and vegetables and peeling roots and tubers can help reduce cadmium contamination.

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- Promote safe and effective measures to increase recycling of cadmium and to restrict non-recyclable uses.
- Promote the elimination of the use of cadmium in products such as toys, jewellery and plastics.
- Reduce cadmium exposure by, for instance, improving working conditions in the non-ferrous metal smelting industry and disseminating information on the proper selection of fertilisers (which sometimes contain high levels of cadmium).
- Raise global awareness on the importance of minimising waste discharges of cadmium.

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Coordinating agency or organisation

World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations.

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0103 / CHEMICAL / Heavy Metals and Trace Elements

Lead

Definition

Lead is a naturally occurring, highly toxic heavy metal. Its widespread use has caused extensive environmental contamination and health problems in many parts of the world. It is a cumulative toxicant that affects multiple body systems, including the neurological, haematological, gastrointestinal, cardiovascular and renal systems. Children are particularly vulnerable to the neurotoxic effects of lead, and even relatively low levels of exposure can cause serious and, in some cases, irreversible neurological damage (WHO, 2024).

Preliminary – Corrections Pending

Reference

WHO, 2024. Lead poisoning. World Health Organization (WHO). Lead poisoning Accessed 2 May 2025.

Annotations

GHS Classification (UNECE, 2023)

Synonyms

Pb, plumbum

Additional scientific description

Lead (chemical symbol Pb, atomic number 82) is found at low levels in the Earth's crust, mainly as lead sulfide (WHO, 2024). Lead has been known since ancient times. It is sometimes found free in nature, but is usually obtained from the ores galena (PbS), anglesite (PbSO4), cerussite (PbCO3) and minum (Pb3O4) (PubChem no date). However, the widespread occurrence of lead in the environment is largely the result of human activity, such as mining, smelting, refining and informal recycling of lead; use of leaded petrol (gasoline); production of lead-acid batteries and paints; jewellery making, soldering, ceramics and leaded glass manufacture in informal and 'cottage' (home-based) industries; electronic waste; and use in water pipes and solder (WHO, 2024). Other sources of lead in the environment include natural activities, such as volcanic activity, geochemical weathering and sea spray emissions, and remobilisation of historic sources, such as lead in soil, sediment and water from mining areas. As lead is a natural element, once it is released into the environment, it persists. Owing to lead's persistence and potential for global atmospheric transport, atmospheric emissions affect even the most remote regions of the world (WHO, 2024).

Acute exposures to lead may cause gastrointestinal disturbances (anorexia, nausea, vomiting, abdominal pain), hepatic and renal damage, hypertension and neurological effects (malaise, drowsiness, encephalopathy) that may lead to convulsions and death. Chronic exposure effects include haematological effects, such as anaemia, or neurological disturbances, including headache, irritability, lethargy, convulsions, muscle weakness, ataxia, tremors and paralysis. Pregnant women are particularly vulnerable; for example, in-utero exposure of the foetus at maternal blood lead levels of less than 5 mg/dL can lead to reduced foetal growth and lower birth rate, and the mother may experience eclampsia and decreased renal function at these blood lead levels. Developing children are particularly vulnerable to lead exposure, with learning disorders and other neurological and developmental disorders occurring at blood lead levels lower than those of adults (US Department of Health and Human Services, 2012).

It has been estimated that lead exposure was responsible, in 2004, for 143,000 deaths and 0.6% of the global burden of disease (expressed in disability-adjusted life years, or DALYs), taking into account mild mental retardation and cardiovascular outcomes resulting from exposure to lead. Young children absorb four to five times as much lead as adults (apart from pregnant women). Infants, young children (especially those less than five years of age) and pregnant women are most susceptible to the adverse effects of lead. The most critical effect of lead in young children is on the developing nervous system. Subtle effects on intelligence quotient (IQ) are expected from blood lead levels at least as low as 5 µg/dL (50 µg/L), and the effects gradually increase with increasing levels of lead in blood (WHO, 2024).

Metrics and numeric limits

The World Health Organization (WHO) has published lead guidelines for drinking-water and air (WHO, 2024): Drinking-water: 10 µg/L. Air: 0.5 µg/m^3 (annual average).

Key relevant UN convention / multilateral treaty

International Labour Organisation C013 - White lead (painting) convention, 1921 (ILO, 1921).

Examples of hazard drivers, impacts and risk management

Hazard Drivers. Significant sources of exposure to lead still remain, particularly in developing countries (WHO, 2024).

Further efforts are required to continue to reduce the use and release of lead and to reduce environmental exposures, particularly for children and women of child-bearing age (WHO, 2024). Recent reductions in the use of lead in petrol (gasoline), paint, plumbing and solder have resulted in substantial reductions in lead levels in the blood.

In terms of industrial processes, lead is used mainly in the production of lead-acid batteries, plumbing materials and alloys. Other uses are in cable sheathing, paints, glazes and ammunition. Mining, smelting, and informal processing and recycling of electric and electronic waste can also be significant sources of exposure. Lead has been used widely in the form of tetraethyl and tetramethyl lead as antiknock and lubricating agents in petrol, although the majority of lead is emitted from vehicles in the form of inorganic particles. This use has been phased out in most countries, which has resulted in a significant reduction of human exposure and mean blood lead levels. In the few parts of the world where leaded petrol is still in use, however, it continues to be a major source of exposure. Old industrial hotspots that have not been cleaned up can also represent a hazard.

Impacts. Even years after contamination has stopped, particularly to children who might ingest contaminated soil or dust as a result of their hand-to-mouth behaviour and pica (WHO, 2024).

For the non-smoking general population, the largest contribution to the daily intake of lead is from the ingestion of food, dirt and dust. The amount of lead in food plants depends on soil concentrations and is highest around mines and smelters. Cereals can contain high levels of lead, and spices may be contaminated with lead. Use of lead-soldered food and beverage cans (which is now diminishing) may considerably increase the lead content of the food or beverage, especially in the case of acidic foods or drinks. As fruit juices and various alcoholic drinks tend to be acidic, the use of any lead-containing products in their manufacture, distribution or storage will raise lead levels. Migration of lead into food from lead-glazed ceramic or pottery dinnerware is also a source of exposure. Smoking tobacco increases lead intake (WHO, 2024).

Lead present at elevated levels in tap water is rarely the result of its dissolution from natural sources but is often due to old household plumbing systems containing lead pipes, solder and fittings. Soft acidic water dissolves the most lead (WHO, 2024).

Contaminated dust may be the main source of exposure for infants in countries that no longer use leaded petrol. The weathering, peeling or chipping of lead-based paints, mainly found in older houses, plays a role in children's

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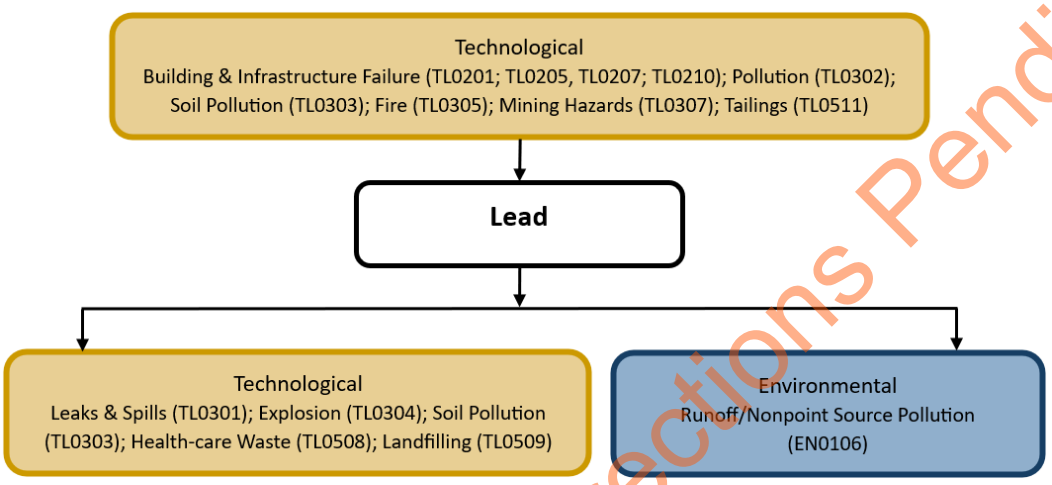
exposure, especially as some young children eat the fragments or lick dust-laden fingers. Lead-containing dust may be brought into the home on the clothes of those who work in industries where such dust is generated. Some toys are either made from lead or contain lead (e.g., some plastics or paints). Some traditional medicines and makeup (e.g., kohl) contain lead (WHO, 2024).

Primary prevention (i.e., the elimination of exposure to lead at its source) is the single most effective intervention against childhood lead poisoning (WHO, 2024).

Multi-hazard Context: The figure below summarises common interactions between lead and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring lead. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Water agencies, Environmental agencies, health agencies
How is the Hazard Observed/Monitored/Forecast?	Monitoring the level of lead in dust, soil and tap water

Risk Management. The following actions for eliminating use are needed:

- Phase out the use of lead additives in motor fuels in countries where this has not yet been done.
- Phase out the use of lead in paints on a worldwide basis.
- Eliminate the use of leaded solder in food and drink cans, as well as in water pipes.
- Eliminate the use of lead in homes, schools, school materials and children's toys.
- Eliminate the use of lead glazing for pottery intended for cooking, eating or drinking.
- Encourage the removal of plumbing and fittings containing lead (as this is costly, other measures, such as corrosion control and minimising the dissolving of lead in water systems, should be implemented in the meantime).
- Identify and eliminate lead use in traditional medicines and cosmetics.
- Establish sentinel systems that include human biomonitoring, possibly most easily facilitated via a network of recognised analytical laboratories.
- The WHO provides recommendations (WHO, 2024) on preventing exposure to lead from electric and electronic waste (e.g., lead-acid batteries, computers), particularly for children, which include:
    - Ensure that the recycling of lead-containing waste is undertaken only in the presence of appropriate industrial hygiene measures and that informal recycling and use of lead-containing waste are discouraged.

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- Identify contaminated sites and take necessary action to prevent human exposure to lead from these areas.
- Prevent pica of paint chips in homes previously painted with lead-based paint.
- Follow good practices, including personal protective equipment and barriers, during rehabilitation, deconstruction, decommissioning, and other work in and near buildings and structures that may have been painted with lead-based paint.

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Coordinating agency or organisation

World Health Organization (WHO).

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0104 / CHEMICAL / Heavy Metals and Trace Elements

Mercury

Definition

Mercury is a naturally occurring element that is found in air, water and soil. Exposure to mercury, even small amounts, may cause serious health problems and is a threat to the development of the foetus in utero and for children early in life (WHO, 2021).

Reference

WHO, 2024. Mercury (WHO). Mercury Accessed 2 May 2025.

Annotations

GHS Classification (UNECE, 2023)

Synonyms

Hg, Quicksilver, Hydrargyrum, Elemental Mercury, Metallic Mercury, Liquid Mercury, Azogue, and Cinnabar

Additional scientific description

Mercury (chemical symbol Hg, atomic number 80) exists in various forms: elemental mercury (metallic or vapour) and inorganic mercury compounds (to which people may be exposed, for example, through their occupation); and organic (or organometallic) mercury compounds (for example, methylmercury, to which people may be exposed through their diet). These forms of mercury differ in their degree of toxicity and toxic effects (WHO, 2021).

Mercury occurs naturally in the Earth's crust (UNEP, 2018). It is released into the environment from volcanic activity, weathering of rocks and as a result of human activity. Human activity is the main cause of mercury releases, particularly coal-fired power stations, residential coal burning for heating and cooking, industrial processes, waste incinerators and as a result of mining for mercury, gold and other metals (WHO, 2021). Mercury has been used in dental amalgam for tooth fillings. Methylmercury has a history as a fungicide. Organic mercury compounds are used as protective agents in biochemistry.

Mercury may have toxic effects on the nervous, digestive and immune systems, and on the lungs, kidneys, skin and eyes. The World Health Organization considers mercury to be one of the top ten chemicals or groups of chemicals of major public health concern. People are mainly exposed to mercury in the form of methylmercury, an organometallic compound, when they eat fish and shellfish that contain this compound (WHO, 2021).

Once in the environment, elemental mercury can be transformed into methylmercury and consumed by phytoplankton in seawater and by sulphate-reducing bacteria in freshwater sediments. Methylmercury then bioaccumulates (the process by which an organism contains progressively higher concentrations of the substance than its surroundings) in fish and shellfish. Methylmercury also biomagnifies up food chains: for example, large predatory fish are more likely to have high levels of methylmercury as a result of eating many smaller fish that have acquired methylmercury through ingestion of plankton (WHO, 2021).

Use of elemental mercury in some traditional therapies, religions and practices (e.g., Santería, Espiritismo) represents a risk of exposure due to the practice itself or from accidental spills. However, the extent of the problem is unknown. Use of mercury-containing beauty creams, hair treatment and other cosmetic products may cause significant exposure (WHO, 2021).

Health effects from mercury (WHO, 2021) are summarised as follows:

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- Inhalation of mercury vapour can produce harmful effects on the nervous, digestive and immune systems, lungs and kidneys, and may be fatal. The inorganic salts of mercury are corrosive to the skin, eyes and gastrointestinal tract, and may induce kidney toxicity if ingested.
- Neurological and behavioural disorders may be observed after inhalation, ingestion or dermal application of different mercury compounds. Symptoms include tremors, insomnia, memory loss, neuromuscular effects, headaches and cognitive and motor dysfunction. Mild subclinical signs of central nervous system toxicity can be seen in workers exposed to an elemental mercury level in the air of 20 µg/m^3 or more for several years. Kidney and immune effects have been reported. There is no conclusive evidence linking mercury exposure to cancer in humans.
- Children are especially vulnerable to mercury and may be exposed directly by eating contaminated fish. Methylmercury bioaccumulates in fish and if consumed by pregnant women may lead to neurodevelopmental problems in the developing foetus. Transplacental exposure is the most dangerous, as the foetal brain is very sensitive. Neurological symptoms include mental retardation, seizures, vision and hearing loss, delayed development, language disorders and memory loss. In children, a syndrome characterised by red and painful extremities called acrodynia has been reported to result from chronic mercury exposure.

Metrics and numeric limits

Guidance values are complex, but in summary, the following may be helpful:

- Drinking-water: 0.006 mg/L (6 µg/L) for inorganic mercury (WHO, 2011).
- Provisional tolerable weekly intake: for methylmercury in food of 1.6 µg/kg body weight (JECFA, 2007).
- Air: lowest-observed-adverse-effect level (LOAELs) for mercury vapour are around 15–30 µg/m^3 (WHO, 2000).

Key relevant UN convention / multilateral treaty

Minamata Convention on Mercury (UNEP, 2013).

Examples of hazard drivers, impacts and risk management

Hazard Drivers. Mercury is emitted to the atmosphere by (a) primary anthropogenic sources, including artisanal and small-scale gold mining (ASGM), fossil fuel combustion, and metal smelting; (b) re-emissions of historical anthropogenic ("legacy") Hg from ocean and land; and (c) geogenic sources.

Impacts. All humans are exposed to mercury. Factors that determine whether health effects occur, and their severity include: the chemical form of mercury concerned; the dose; the age or developmental stage of the person exposed (the foetus is most susceptible); the duration of exposure; and the route of exposure (inhalation, ingestion or dermal contact) (WHO, 2021).

Generally, two groups are more sensitive to the effects of mercury. Foetuses are most susceptible to developmental effects due to mercury potentially leading to impaired neurological development with cognitive thinking, memory, attention, language, and fine motor and visual spatial skills affected. The second group is people who are regularly exposed (chronic exposure) to high levels of mercury (such as populations that rely on subsistence fishing or people who are occupationally exposed). Among selected subsistence fishing populations, between 1.5/1000 and 17/1000 children showed cognitive impairment (mild mental retardation) associated with the consumption of fish containing mercury (WHO, 2021).

A significant example of mercury exposure affecting public health occurred in Minamata, Japan, between 1932 and 1968, where a factory producing acetic acid with a mercury catalyst discharged inorganic mercury into Minamata Bay. The bay was rich in fish and shellfish, providing the main livelihood for local residents and fishermen from other areas. For many years, no one realised that the fish were contaminated with mercury, and that it was causing a strange disease in the local community and in other districts. At least 50,000 people were affected to some extent and more than 2000 cases of Minamata disease were certified. Minamata disease peaked in the 1950s, with severe cases suffering brain damage, paralysis, incoherent speech and delirium. The continued release of mercury into the environment from human activity, the presence of mercury in the food chain, and the demonstrated adverse effects on humans are of such concern that in 2013, governments agreed to the Minamata Convention on Mercury. The Convention obliges Parties to take a range of actions, including to address mercury emissions to air and to phaseout certain mercury-containing products (WHO, 2019).

Documented accidents involving mercury have occurred in various industries and settings, leading to significant health and environmental impacts.

Accidental spills or releases of mercury, particularly in industrial settings such as chemical plants, laboratories, and gold mining operations, can lead to contamination of air, soil, and water. Exposure to mercury vapor or ingestion of mercury-contaminated food or water can cause acute poisoning, with symptoms including respiratory problems, neurological disorders, and gastrointestinal issues (ATSDR, 2022).

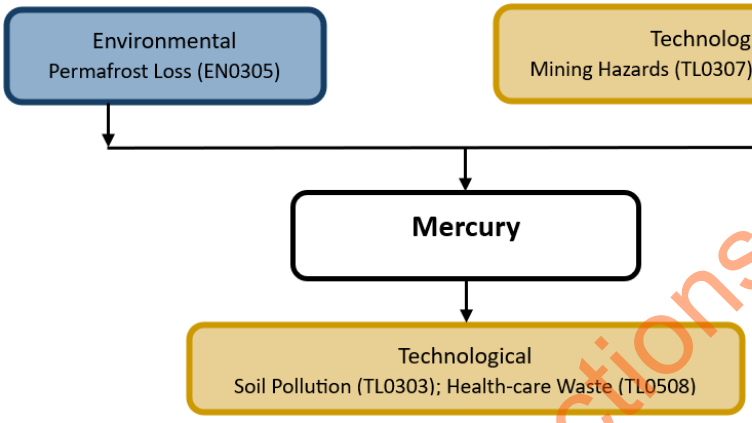
Improper handling and disposal of mercury-containing dental amalgam waste have led to environmental contamination and

Preliminary – Corrections Pending

health risks for dental professionals and patients. Mercury released from dental amalgam fillings during placement, removal, or cremation can contribute to environmental pollution and human exposure.

Artisanal and Small-Scale Gold Mining (ASGM): Mercury is often used in ASGM to extract gold from ore. Improper handling and disposal of mercury during gold extraction processes can lead to environmental contamination, particularly in water bodies. ASGM communities and workers are at risk of mercury exposure, resulting in health problems such as neurological disorders, kidney damage, and developmental issues in children (Spiegel et al., 2018).

Multi-hazard Context: The figure below summarises common interactions between mercury. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring mercury. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	The United Nations Environment Programme (UNEP) works on global initiatives to red mercury emissions and exposure.
How is the Hazard Observed/Monitored/Forecast?	The Global Mercury Observation System (GMOS) is an early warning system designe monitor mercury levels in the environment.

Risk Management: There are several ways to prevent adverse health effects of mercury, including promoting clean energy, stopping the use of mercury in gold mining, eliminating the mining of mercury and phasing out non-essential mercury-containing products.

- Promote the use of clean energy sources that do not burn coal. Burning coal for power and heat is a major source of mercury. Coal contains mercury and other hazardous air pollutants that are emitted when the coal is burned in coal-fired power plants, industrial boilers and household stoves (WHO, 2021).
- Eliminate mercury mining and use of mercury in gold extraction and other industrial processes. Mercury is an element that cannot be destroyed; therefore, mercury already in use can be recycled for other essential uses, with no further need for mercury mining. Mercury use in artisanal and small-scale gold mining is particularly hazardous, and health effects on vulnerable populations are significant. Non-mercury (non-cyanide) gold-extraction techniques need to be promoted and implemented, and where mercury is still used, safer work practices need to be employed to prevent exposure (WHO, 2021).
- Phase out use of non-essential mercury-containing products and implement safe handling, use and disposal of remaining mercury-containing products including batteries, measuring devices, such as thermometers and barometers, electric switches and relays in equipment, lamps (including some types of light bulbs), dental amalgam (for dental fillings), skin lightening products and other cosmetics and pharmaceuticals (WHO, 2021).
- Establish a sentinel system to detect hazardous substances.

Key aspects of mercury risk management include:

Objectives:

1. Monitoring: Track mercury levels in air, water, soil, and biota (plants and animals).
2. Data Collection: Gather data on mercury emissions from various sources, including natural sources like volcanic activity

Preliminary – Corrections Pending

and anthropogenic sources like industrial processes.

3. Risk Assessment: Assess the risk posed by mercury exposure to human health and the environment.
4. Policy Support: Provide data to inform and support policies aimed at reducing mercury emissions and exposure.

Components:

1. Sensors and Sampling Stations: Deploy sensors and sampling stations globally to continuously measure mercury concentrations.
2. Data Analysis: Use advanced analytical techniques to interpret the collected data and identify trends.
3. Modelling: Develop models to predict the dispersion and deposition of mercury in the environment.
4. Reporting and Communication: Communicate findings to stakeholders, including governments, environmental agencies, and the public.

Challenges:

1. Coverage: Ensuring comprehensive global coverage to accurately monitor mercury levels in different regions.
2. Accuracy: Maintaining the accuracy and reliability of data collected from various sources.
3. Collaboration: Coordinating efforts among multiple countries and organizations to create a unified monitoring system.
4. Response: Developing effective response strategies to mitigate the impact of mercury exposure.

Importance:

1. Health Impact: Mercury exposure can lead to serious health issues, including neurological and developmental problems, particularly in children and foetuses.
2. Environmental Impact: Mercury can bioaccumulate in the food chain, affecting wildlife and ecosystems.
3. Policy Development: Accurate data on mercury levels is essential for creating effective environmental policies and regulations.

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Coordinating agency or organisation

Preliminary – Corrections Pending

World Health Organization (WHO), Food and Agriculture Organization of the United Nations (FAO), International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0105 / CHEMICAL / Heavy Metals and Trace Elements

Fluoride and Iodine/Iodide Excess or Inadequate Intake

Definition

Fluoride is a naturally occurring mineral to which the public is often exposed via drinking water. Depending on dose intake, fluoride may have beneficial effects (reducing the incidence of dental caries) or negative effects (causing tooth enamel and skeletal fluorosis following prolonged high exposure) (adapted from NCBI, 2020 and WHO, no date). Some water supplies are fluoridated in order to achieve improved dental health.

Iodine is a non-metallic element essential for the human body, as it is a crucial component of thyroid hormones, which regulate various metabolic processes, including growth and energy expenditure. Iodine, usually as iodide salts in the diet, is absorbed throughout the gastrointestinal tract. Iodine is essential for healthy brain development in the foetus and young child. A deficiency in iodine can lead to thyroid gland problems, such as goitre and hypothyroidism. Iodine deficiency negatively affects the health of women, as well as economic productivity and quality of life (WHO, 2023). Food fortification (often with potassium iodide, KI) is sometimes used to address iodine deficiency.

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Annotations

GHS Classification (UNECE, 2023)

Synonyms

Fluoride: Fluorine Ion, Fluoride Ion, Hydrogen Fluoride (HF), Sodium Fluoride (NaF), Calcium Fluoride (CaF_2), Fluoride Salt.

Iodine: Elemental Iodine, Iodide (I^-), Iodate (IO_3^-), Iodine Solution, Lugol's Solution, Iodophor.

Additional scientific description

Fluorine and iodine, together with chlorine, bromine, astatine and tennessine are elements from Group 17 in the Periodic Table, also known as the Halogen family. Halides, the anions from Group 17 such as **fluoride**, chloride, bromide, **iodide,** etc., are considered additionally as phytotoxic air pollutants and can have a severe impact on health at high or low concentrations.

Fluoride is the anion (negatively charged ion with the symbol "F^-" of fluorine (chemical element with the symbol "F" and atomic number 9), and it is found in various forms, both in nature and in synthetic products. Fluoride can be released into the environment in several ways: (i) natural activities, such as volcanic emissions, weathering of minerals and dissolution, particularly into groundwater; (ii) human activities, such as the production and use of phosphate fertilizers; manufacture and use of hydrofluoric acid and production of aluminium, steel and oil; and (iii) remobilization of historic sources, such as water flow and sediment movement from aluminium production plants.

The beneficial effect of fluoride includes the minimization of tooth decay and caries. Public health action to provide sufficient fluoride intake can be achieved through drinking water fluoridation or, when this is not possible, through salt or milk fluoridation or use of dental care products containing fluoride (WHO, no date).

Excessive fluoride intake usually occurs through the consumption of groundwater naturally rich in fluoride, particularly in warm climates where water consumption is greater, or where high-fluoride water is used in food preparation or irrigation of crops such as rice. In these areas, measures should be sought to manage intakes by providing drinking-water with a moderate (i.e., safe) fluoride level or using alternative sources of water for drinking, cooking or irrigation. The preparation of food using fluoride-rich coal also contributes to excessive fluoride intake via ingestion and inhalation (WHO, 2019).

Iodine is a chemical element with the symbol "I" and atomic number 53. Iodine is essential for healthy brain development in the foetus and young children. Iodine deficiency negatively affects the health of women, as well as economic productivity and quality of life. Iodine's physiologic role in the human body is in the synthesis of thyroid hormones by the thyroid gland. Dietary iodine is converted into the bio-available iodide ion "I^-" before it is absorbed from food and water, enters the circulation as plasma inorganic iodide, which is cleared from circulation by the thyroid and kidney. Excess iodide is excreted by the kidney in urine. For determining the iodine requirements, the important indexes are serum T_4 and TSH levels (indicating normal thyroid status) and urinary iodine excretion (FAO 2002).

Most people need an additional source of iodine as it is found in relatively small amounts in the diet. Iodization is the process of fortifying salt for human consumption with iodine and is an effective strategy to increase iodine intake at the population level. Monitoring the levels of iodine in salt and the iodine status of the population is critical for ensuring that the population's needs are met and not exceeded.

Iodine contamination poses significant health risks, including thyroid dysfunction and increased cancer risk, particularly from radioactive isotopes like iodine-131 (CDC, 2024). Environmental impacts include disruption of aquatic ecosystems and soil quality degradation (Cox et al. 2014). Effective monitoring and management strategies are essential to mitigate these risks and protect both public health and the environment.

Metrics and numeric limits

Fluoride

World Health Organization (WHO) fluoride guideline values (WHO, 2019):

Drinking water: The guideline value for fluoride in drinking water is 1.5 mg/L, based on increasing risk of dental fluorosis at higher concentrations and that progressively higher levels of fluoride lead to increasing risk of skeletal fluorosis. This value is higher than that recommended for artificial fluoridation of water supplies for the prevention of dental caries, which is usually 0.5–1.0 mg/L. The WHO recommends that, in setting a standard, Member States should take into account drinking water consumption and fluoride intake from other sources.

Air: The guideline value is 1 µg/m^3 (developed to prevent effects on livestock and plants and is also considered sufficiently protective of human health).

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Iodine / Iodide

World Health Organization (WHO) iodine deficiency values. From: Vitamin and Mineral Nutrition Information System (VMNIS). Micronutrients database (http://www.who.int/vmnis/database/en/) Accessed 31 July 2024.

Iodine deficiency measured by median urinary iodine concentration (µg/L) in school-age children (≥6 years): <20 µg/L – Insufficient - Severe deficiency, 20-49 µg/L – Insufficient - Moderate deficiency, 50-99 µg/L – Insufficient - Mild deficiency, 100-199 µg/L – Adequate, Adequate iodine nutrition, 200-299 µg/L - Above requirements - May pose a slight risk of more than adequate iodine intake in these populations, ≥300 µg/L – Excessive - Risk of adverse health consequences (e.g. iodine-induced hyperthyroidism or autoimmune thyroid disease).

Iodine deficiency measured by median urinary iodine concentration (µg/L) in pregnant women: <150 µg/L – Insufficient, 150-249 µg/L – Adequate, 250-499 µg/L - Above requirements, ≥500 µg/L – Excessive. Iodine deficiency measured by median urinary iodine concentration (µg/L) in lactating women and children aged <2 years: <100 µg/L – Insufficient, ≥100 µg/L – Adequate

Key relevant UN convention / multilateral treaty

The World Health Organization (WHO), United Nations Children's Fund (UNICEF), and other international bodies advocate for universal salt iodization (USI) as a strategy to eliminate iodine deficiency disorders (IDD) globally.

Examples of hazard drivers, impacts and risk management

Hazard Drivers

Fluoride contamination: Natural Sources: Geological Activity and Hot Springs. Anthropogenic (Human-Caused) Sources: Industrial Processes, Agricultural Activities, and Coal Burning.

Iodine contamination: Natural Sources: Geological Activity and Hot Springs. Anthropogenic (Human-Caused) Sources: Industrial Processes, Agricultural Activities, and Coal Burning. In addition, iodine release into the atmosphere could occur from volcanic eruptions, which eventually deposits onto land and water bodies. Iodine-131, a radioactive isotope of iodine, can be released during nuclear accidents or improper disposal of nuclear waste, leading to contamination of air, soil, and water.

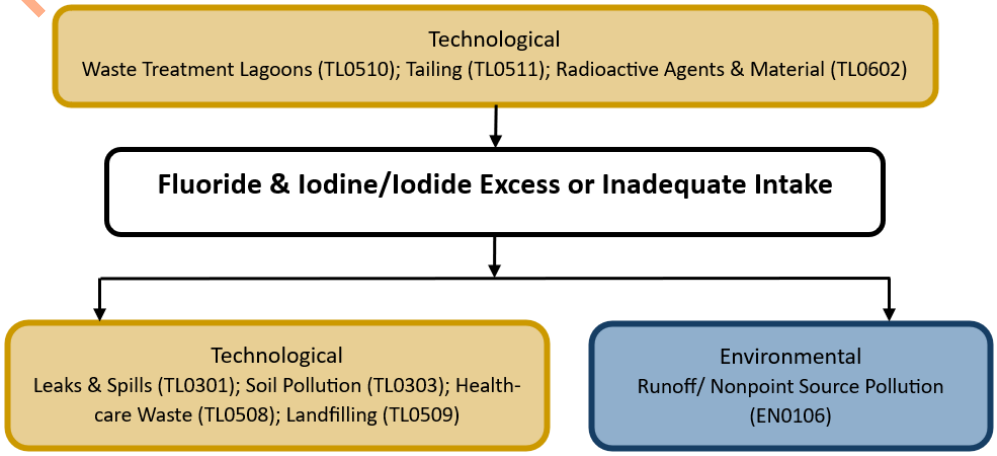
Impacts

Fluoride contamination: Two worldwide public health concerns related to fluoride need to be addressed: the need to reduce dental caries and the need to mitigate the effects of excessive fluoride intake. Thus, public health actions are required to provide sufficient fluoride intake where this is lacking, to minimize tooth decay, as well as to provide drinking water with a moderate (i.e., safe) fluoride level in areas where groundwater contains high fluoride levels (WHO, 2019).

To provide guidance on the need to control population exposure to fluoride and establish the balance between caries prevention and protection against adverse effects of fluoride, community health programmers can estimate total exposure by measuring renal fluoride excretion and compare these levels with established optimal levels using methods published by the WHO. However, risk mitigation measures implemented should also take into consideration local contexts and sensitivities (WHO, 2019).

Iodine contamination on human health: Thyroid Dysfunction: Both excessive and insufficient iodine intake can disrupt thyroid function. Excessive iodine can lead to hyperthyroidism, while insufficient iodine can cause hypothyroidism and goitre. Iodine Toxicity: Acute iodine toxicity can result from high levels of iodine intake, leading to symptoms such as abdominal pain, vomiting, and diarrhoea. Chronic exposure to high iodine levels may cause more severe health issues, including thyroiditis and thyroid cancer. Radioactive Iodine Exposure: Exposure to iodine-131 from nuclear accidents can increase the risk of thyroid cancer, particularly in children.

Multi-hazard Context: The figure below summarises common interactions between fluoride and Iodine/iodide excess or inadequate intake and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



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Monitoring: The section and the table below offer an overview of monitoring fluoride and Iodine/iodide excess or inadequate intake. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	World Health Organization (WHO): "Guidelines for Drinking-water Quality". Food and Agriculture Organization of the United Nations (FAO): "Global assessment of soil pollution Report". Environmental Protection Agency (EPA): "National Primary Drinking Water Regulations".
How is the Hazard Observed/Monitored/Forecast?	WHO provides comprehensive guidelines on the permissible levels of various contaminants, including fluoride and iodide, in drinking water to ensure safety and health. EPA sets standards for drinking water contaminants, including fluoride and iodide, under the Safe Drinking Water Act. These regulations ensure the safety of public drinking water supplies in the United States.

Risk Management:

The WHO recommends (WHO, 2019) that the following actions are required to provide adequate fluoride or control excess through the following measures.

Inadequate fluoride intake:

- Fluoridating low-fluoride drinking water where practicable, as well as considering alternatives, such as salt or milk fluoridation.
- Reduce the incidence of dental caries by: Developing effective and affordable fluoridated toothpastes for use in developing countries. Promoting optimal oral hygiene, based on the use of effective fluoridated toothpaste, guidance on the amount of fluoridated toothpaste to and exposure to other sources of fluoride in the community. Supporting the use of silver diamine fluoride and atraumatic restoration treatment, and other minimally invasive techniques, using glass ionomer cement to stabilize caries lesions.

Irrespective of fluoride exposure, advocating a low-sugar diet in accordance with the WHO recommendation that free (added) sugars should not exceed 10% of total energy intake by both adults and children (strong recommendation); the WHO further suggests a reduction to below 5% of total energy intake (conditional recommendation).

Excess fluoride:

- Where practicable, monitor the prevalence of enamel fluorosis using scoring guidance systems such as those developed by the WHO.
- Provide drinking water with fluoride levels that do not produce adverse health effects, by:
  - Seeking alternative water sources in areas with fluoride-rich groundwater, particularly where water consumption is high due to elevated temperatures.
  - Defluoridation of water for drinking and cooking, where an alternative source is not an option, using methods such as bone charcoal adsorption, contact precipitation, coagulation–flocculation/ sedimentation using aluminum sulphate (Nalgonda process), activated alumina adsorption and clay considering local context. Research the appropriateness of community fluoridation schemes in view of natural fluoride levels in water. Water Treatment Technologies for iodine removal include activated carbon filtration, reverse osmosis, ion exchange or alternative water sources.
- Setting Standards: Governments and regulatory bodies should establish and enforce guidelines for maximum allowable fluoride levels in drinking water and industrial emissions.
- Monitor fluoride levels in the environment, especially in areas where there is exposure to elevated fluoride levels due to human activities and determine the overall exposure to fluoride.
- Encourage mothers to breastfeed, even in areas with high fluoride intake, because breast milk is optimal for infant health and usually low in fluoride.

Discourage the use of fluoride-rich coal for cooking purposes.

The WHO recommends (WHO, 2019) that the following actions are required to provide adequate iodine or control excess through the following measures:

Inadequate iodine intake:

- Awareness and Education: Public health campaigns can educate communities on the risks of iodine contamination, safe iodine intake levels, and the importance of proper monitoring.
- Iodine Supplementation Programs: In regions where iodine deficiency is a concern, carefully managed iodine supplementation programs can help ensure adequate iodine intake without exceeding safe levels.

Excess iodine:

- Monitor iodine levels in the environment, especially in areas where there is exposure to elevated iodine levels due to human activities and determine the overall exposure to iodine.

Preliminary – Corrections Pending

- Implement Nuclear Safety Regulations: Stricter regulations and safety measures should be in place to prevent the release of radioactive iodine from nuclear facilities and ensure proper disposal of nuclear waste.

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Coordinating agency or organisation

Preliminary – Corrections Pending

World Health Organization (WHO), Food and Agriculture Organization of the United Nations (FAO).

Preliminary – Corrections Pending

CH0201 / CHEMICAL / Carcinogens

Aflatoxins

Definition

Aflatoxins are mycotoxins – toxic compounds that are naturally produced by certain types of mould (fungi). Aflatoxins are among the most poisonous mycotoxins and are produced by certain moulds (Aspergillus flavus and A. parasiticus) that grow in soil, decaying vegetation, hay, and grains. Aflatoxins pose a serious health risk to humans and livestock (WHO, 2023).

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Annotations

GHS Classification

Synonyms

mycotoxins; aspergillus toxins; fungal toxins; foodborne toxins; carcinogenic mycotoxins

Additional scientific description

Aflatoxins are among the most poisonous of the mycotoxins and place communities as well as individuals at risk. Mycotoxins are toxic compounds that are naturally produced by certain types of mould (fungi). Moulds that can produce mycotoxins grow on many foodstuffs such as cereals, dried fruits, nuts and spices (see CH0601). Mould growth can occur either before harvest or after harvest, during storage, on/in the food itself, often under warm, damp and humid conditions. Most mycotoxins are chemically stable and survive food processing (WHO, 2023).

Aflatoxins are difuranocoumarin derivatives with a bifuran group attached to one side of the coumarin nucleus and either a pentanone ring (B series) or a six-membered lactone ring (G series) on the other side. Major types include: Aflatoxin B1 (AFB1) and B2 (AFB2), Aflatoxin G1 (AFG1) and G2 (AFG2), and Aflatoxin M1 (AFM1) and M2 (AFM2).

Several hundred different mycotoxins have been identified, but the most commonly observed mycotoxins that present a concern to human health and livestock include aflatoxins, ochratoxin A, patulin, fumonisins, zearalenone and nivalenol/deoxynivalenol. Mycotoxins appear in the food chain as a result of mould infection of crops both before and after harvest. Exposure to mycotoxins can happen either directly by eating infected food or indirectly from animals that are fed contaminated feed, especially from milk (WHO, 2023).

Aflatoxins are produced by certain moulds (Aspergillus flavus and A. parasiticus) which grow in soil, decaying vegetation, hay, and grains and the crops that are frequently affected by Aspergillus spp. include cereals (corn, sorghum, wheat, rice), oilseeds (soybean, peanut, sunflower, cotton seeds), spices (chili peppers, black pepper,

Preliminary – Corrections Pending

coriander, turmeric, ginger) and tree nuts (pistachio, almond, walnut, coconut, Brazil nut). Large doses of aflatoxins can lead to acute poisoning (aflatoxicosis) and can be life-threatening, usually through damage to the liver (WHO, 2023). Aflatoxins have been classified as human carcinogens by the International Agency for Research on Cancer (IARC, 2002). Aflatoxins are a particular concern for Africa (WHO, no date).

Metrics and numeric limits

The United Nations food standards body Codex Alimentarius Commission has set the maximum levels for aflatoxin in foods, including various nuts, grains, dried figs and milk (in the range 0.5-15 µg/kg; a microgram is one billionth of a kilogram) (WHO, 2023).

EU 2006: 2 µg/kg for aflatoxin B1 in nuts and dried fruits intended for direct human consumption; 4 µg/kg for total aflatoxins (B1, B2, G1, G2) in nuts and dried fruits.

Codex Alimentarius: 10 µg/kg for total aflatoxins in peanuts intended for further processing; 15 µg/kg for total aflatoxins in other nuts intended for further processing.

Key relevant UN convention / multilateral treaty

Codex Alimentarius (FAO/WHO, no date).

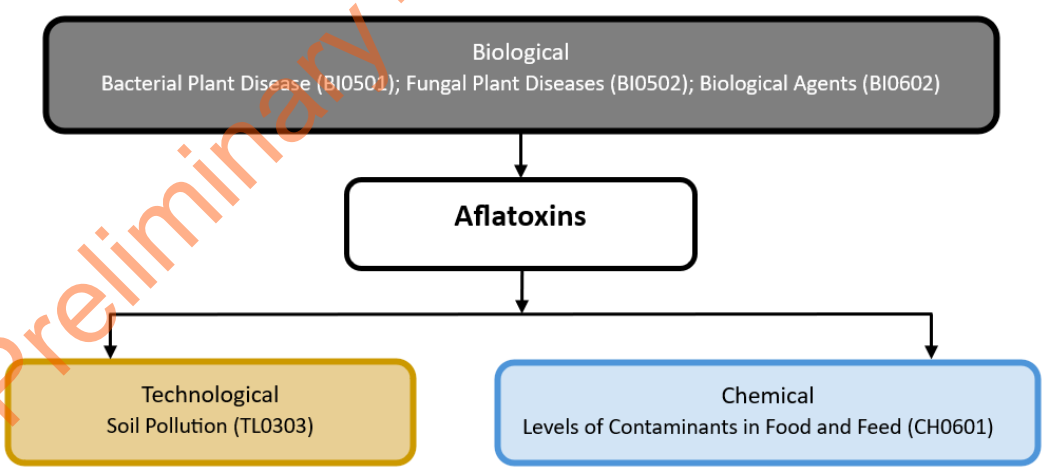
Examples of hazard drivers, impacts and risk management

Hazard Drivers: Mould growth on food and the conditions that promote it are key drivers of aflatoxin poisoning events. Any event that increases consumption of decaying or contaminated food may increase the incidence of aflatoxin poisoning. Thus famines, or events that cause them (e.g. weather events) may increase this risk.

Impacts: Large doses of aflatoxins lead to acute poisoning (aflatoxicosis) that can be life-threatening, usually through damage to the liver. Outbreaks of acute liver failure (jaundice, lethargy, nausea, death), identified as aflatoxicosis, have been observed in human populations since the 1960s. Chronic exposure is responsible for a significant fraction of liver cancer cases in Africa (WHO, no date).

Aflatoxins also pose a significant economic threat (WHO, no date).

Multi-hazard Context: The figure below summarises common interactions between aflatoxins and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring aflatoxins. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	World Health Organization, Food and Agriculture Organization of the United Nations, and national food and agricultural authorities.

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How is the Hazard Observed/Monitored/Forecast?	Monitoring weather conditions around crops and temperature/humidity in storage facilities will identify when the conditions are favourable for mould growth. Mould samples should be collected, cultured and analysed. Surveillance monitoring of food for aflatoxins against metrics and numeric standards will provide warning that levels are rising.

Risk Management: The World Health Organization (WHO) in collaboration with the Food and Agriculture Organization of the United Nations (FAO), is responsible for assessing the risk to humans of mycotoxins, through contamination in food, and for recommending adequate protection. Risk assessments of mycotoxins in food done by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) are used by governments and by the Codex Alimentarius Commission to establish maximum levels in food or provide other risk management advice to control or prevent contamination. Codex standards are the international reference for national food supplies and for food trade, so that people everywhere can be confident that the food they buy meets the agreed standards for safety and quality, no matter where it was produced (FAO/WHO, no date).

The outcome of such health risk assessments can either be a maximum tolerable intake (exposure) level, or other guidance to indicate the level of health concern (such as the Margin of Exposure), including advice on risk management measures to prevent and control contamination, and on the analytical methods and monitoring and control activities. Tolerable daily intakes are used by governments and international risk managers, such as the Codex Alimentarius Commission, to establish maximum levels for mycotoxins in food. The maximum levels for mycotoxins in food are very low due to their severe toxicity (FAO/WHO, no date; JECFA, no date).

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Coordinating agency or organisation

World Health Organization, Food and Agriculture Organization of the United Nations

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0202 / CHEMICAL / Carcinogens

Asbestos

Definition

Asbestos is the term for a group of naturally occurring fibrous silicate minerals widely used historically in building materials and other products (WHO, 2018). All types of asbestos cause lung cancer, mesothelioma, cancer of the larynx and ovary, and asbestosis (fibrosis of the lungs) (WHO, 2018).

Reference

WHO, 2018. Asbestos: elimination of asbestos-related diseases. World Health Organization (WHO). Asbestos: elimination of asbestos-related diseases (who.int) Accessed 30 April 2024.

Preliminary – Corrections Pending

Annotations

GHS Classification (UNECE, 2023)

Synonyms

Chrysotile (white asbestos) and crocidolite (blue asbestos).

Additional scientific description

Asbestos is a Category 1A Carcinogen. Asbestos is known to have carcinogenic potential for humans, based on human evidence. The International Labour Organisation provides safety cards for chrysotile (white asbestos) and crocidolite (blue asbestos) (ILO, no date).

Asbestos has current or historical commercial use due to its extraordinary tensile strength, poor heat conduction, and relative resistance to chemical attack. For these reasons, asbestos is used for insulation in buildings and as an ingredient in a number of products, such as roofing shingles, water supply lines, and fire blankets, as well as clutches and brake linings, gaskets, and pads for automobiles (WHO, 2018).

The main forms of asbestos are chrysotile (white asbestos) and crocidolite (blue asbestos). Other forms include amosite, anthophylite, tremolite and actinolite (WHO, 2018).

All forms of asbestos are carcinogenic to humans. Exposure to asbestos, including chrysotile, causes cancer of the lung, larynx, and ovaries, and also mesothelioma (a cancer of the pleural and peritoneal linings). Asbestos exposure is also responsible for other diseases such as asbestosis (fibrosis of the lungs), and plaques, thickening and effusion in the pleura (WHO, 2018).

Metrics and numeric limits

There is no Threshold Limit for asbestos as it is carcinogenic. It should be completely removed from use and sequestered in ways that prevent human exposure to asbestos.

According to the World Health Organization (WHO), globally, about 125 million people are currently exposed to asbestos at the workplace. In 2004, asbestos-related lung cancer, mesothelioma and asbestosis from occupational exposure resulted in 107,000 deaths and 1,523,000 Disability Adjusted Life Years (DALYs) (WHO, 2014). In addition, nearly 400 deaths have been attributed to non-occupational exposure to asbestos. The burden of asbestos-related diseases is still rising, even in countries that banned its

use in the early 1990s. Owing to the long latency periods attached to the diseases in question, stopping the use of asbestos now will only result in a decrease in the number of asbestos-related deaths after a number of decades (WHO, 2014).

The WHO air quality guidelines for Europe estimate likely lifetime exposure for asbestos based on typical environmental concentrations and the associated health risk factors such as mesothelioma and lung cancer (WHO, 2000:38).

Key relevant UN convention / multilateral treaty

Asbestos Convention, 1986 (ILO, 1962).

Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (Basel Convention, 1989). At the time of writing, there were 187 parties to the Basel Convention.

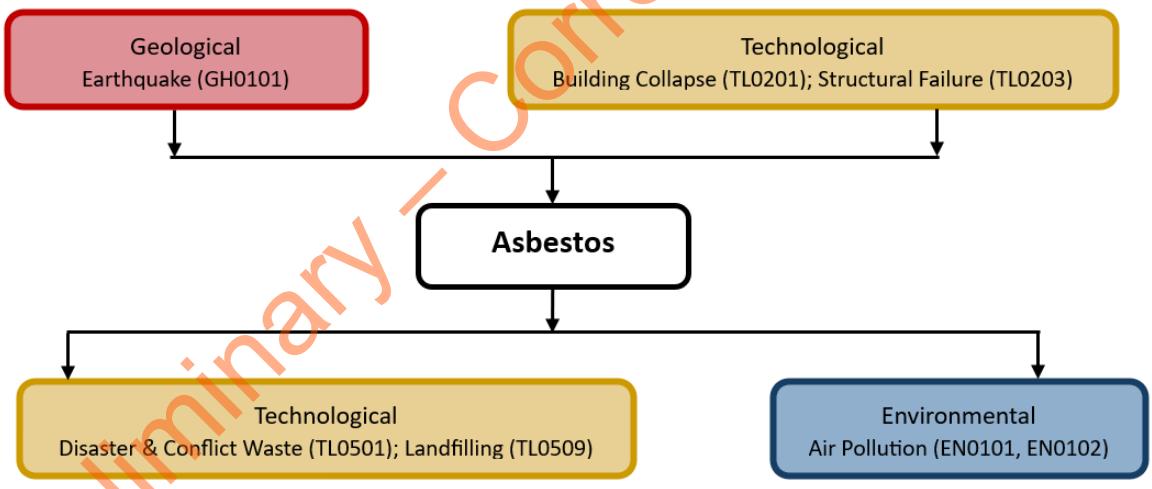
Examples of hazard drivers, impacts and risk management

Hazard drivers: In many disaster-prone areas, asbestos cement is widely used as a building material, and when the material corrodes due to aging or is damaged, it releases harmful asbestos fibres. Fires in buildings can release large amounts of dust and fibres from asbestos and fibreglass insulation (WHO, 2018).

The wide use of asbestos materials in construction means that any event that causes significant damage to buildings and other facilities has the potential to release asbestos dust and fibres (Whitmer, 2024). These represent a significant health hazard. Environmental events that affect opencast asbestos mines may also distribute asbestos dust and fibres.

Impacts: Asbestos is a proven human carcinogen (International Agency for Research on Cancer [IARC] Group 1). No safe level can be proposed for asbestos because a threshold is not known to exist. Exposure should therefore be kept as low as possible (IARC, 1987/1998).

Multi-hazard Context: The figure below summarises common interactions between asbestos and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



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Monitoring: The section and the table below offer an overview of monitoring asbestos. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	ILO, 1962. C162 - Asbestos Convention, 1986 (No. 162) IARC, 1987. Asbestos (Actinolite, amosite, anthophyllite, chrysotile, crocidolite, tremolite) WHO
How is the Hazard Observed/Monitored/Forecast?	As made clear under Drivers, above, asbestos release is often a result of other events that cause damage or fires in the vicinity of asbestos fibres (see Multi-Hazard Context). Early warning will therefore be related to those precipitating events, coupled with good risk management related to mapping areas with high asbestos burdens.

Risk Management: The WHO, in collaboration with the International Labour Organization and other intergovernmental organisations and civil society, works with countries towards the elimination of asbestos-related diseases by (WHO, 2014):

- Recognising that the most efficient way to eliminate asbestos-related diseases is to stop the use of all types of asbestos.
- Providing information about solutions for replacing asbestos with safer substitutes and developing economic and

technological mechanisms to stimulate its replacement.

- Taking measures to prevent exposure to asbestos in place and during asbestos removal (abatement).
- Improving early diagnosis, treatment, and rehabilitation services for asbestos-related diseases.
- Establishing registries of people with past and/or current exposures to asbestos and organising medical surveillance of exposed workers.
- Mapping of areas known to have high asbestos burdens may assist with disaster response.
- Providing information on the hazards associated with asbestos-containing materials and products, and by raising awareness that waste containing asbestos should be treated as hazardous waste.

Cost-effective interventions for preventing occupational lung diseases from exposure to asbestos are among the policy options for implementing the Global Action Plan for the Prevention and Control of Noncommunicable Diseases (2013-2020), as endorsed by the Sixty-sixth World Health Assembly in 2013 (WHO, 2013).

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Coordinating agency or organisation

World Health Organization (WHO), International Programme on Chemical Safety (IPCS)

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0203 / CHEMICAL / Carcinogens

Benzene and Hydrocarbons

Definition

Hydrocarbons are organic compounds composed entirely of hydrogen (H) and carbon (C) atoms. They are the simplest form of organic molecules and are the main components of fossil fuels such as coal, natural gas, and petroleum. Benzene is a clear, colourless, highly flammable and volatile liquid aromatic hydrocarbon (molecular formula C_6H_6) with a gasoline-like odour, which can lead to major public hazards. Benzene is the simplest aromatic hydrocarbon, characterised by alternating single and double bonds between the carbon atoms, forming a delocalized π-electron system. (WHO, 2019) The release of hydrocarbon ground gases, such as methane, can lead to major public hazards.

Reference

WHO, 2019. Preventing disease through healthy environments: Exposure to benzene: a major public health concern. World Health Organization (WHO). apps.who.int/iris/bitstream/handle/10665/329481/WHO-CED-PHE-EPE-19.4.2-eng.pdf?ua=1 Accessed 6 October 2024.

Preliminary – Corrections Pending

Annotations

GHS Classification (UNECE, 2023)

Synonyms

Paraffins; olefins; acetylenes; aromatic compounds; saturated hydrocarbons; unsaturated hydrocarbons; petrochemicals; benzol; phenyl hydride; cyclohexatriene; arene; coal naphtha.

Additional scientific description

Benzene (ICSC 0015, 2016) melts at 5.5°C and boils at 80.1°C; and has a high vapour pressure, which causes it to evaporate rapidly at room temperature, and is highly flammable. Methane and other light hydrocarbons exhibit similar properties. Benzene is slightly soluble in water but miscible with most other organic solvents (IPCS, 1993).

Benzene is used as a solvent in the chemical and pharmaceutical industries. It also occurs naturally in petroleum products (e.g., crude oil and gasoline) at levels up to 4 g/L. The primary route of benzene exposure and subsequent toxicity is via inhalation. The highest exposures have typically been in the workplace, for example, in industries that make or use benzene. The general population may be exposed through the inhalation of contaminated air, particularly in areas of heavy automobile traffic, gas stations and areas near industrial sources. Other sources include cigarette smoking, second-hand smoke, off-gassing from building

materials and structural fires. People also may be exposed to benzene in contaminated drinking-water and some foods (WHO, 2019).

The compulsory introduction of catalytic converters on car exhausts and legislation to reduce benzene levels in car fuels have contributed to a reduction of benzene emissions. Other interventions to prevent or reduce exposures to airborne benzene include promoting the use of alternative solvents in industrial processes, developing and implementing policies and legislation to remove benzene from consumer products, discouraging domestic use of benzene-containing products, promoting building codes requiring detached garages, and implementing the World Health Organization (WHO) Framework Convention on Tobacco Control (WHO, 2003), including providing for protection from exposure to tobacco smoke in workplaces and public areas.

Metrics and numeric limits

Drinking water: The WHO guideline value for benzene is 0.01 mg/L. This is based on extrapolation of modelled excess lifetime risk for leukaemia from epidemiological studies involving inhalation exposure; guideline values corresponding to modelled excess lifetime cancer risks of 10^{-4}, 10^{-5} and 10^{-6} are 0.1, 0.01 and 0.001 mg/L, respectively (WHO, 2019).

An excess lifetime cancer risk of 10^{-4}, 10^{-5} or 10^{-6} means the risk of one new cancer case above background levels per 10,000, 100,000 or 1 million people, respectively.

Air: No specific WHO guideline value has been developed for benzene in air. Benzene is carcinogenic to humans, and no safe level of exposure can be recommended. For general guidance, the concentrations of airborne benzene associated with an excess lifetime risk of leukaemia of 10-4, 10-5 and 10-6 are 17, 1.7 and 0.17 µg/m^3, respectively (WHO, 2019).

Benzene has a flash point: -11.1°C (12°F), making it highly flammable; a vapour pressure of 12.7 kPa at 25°C making it a volatile liquid. The Occupational Exposure Limit (OEL) for benzene is strictly regulated due to its toxicity and carcinogenicity (NIOSH, 2020; OSHA, 2024; EPA, 2024):

- OSHA Permissible Exposure Limit (PEL): 1 part per million (ppm) as an 8-hour time-weighted average (TWA).
- NIOSH Recommended Exposure Limit (REL): 0.1 ppm over a 10-hour workday.
- ACGIH Threshold Limit Value (TLV): 0.5 ppm TWA, with a short-term exposure limit (STEL) of 2.5 ppm.

Alkanes (Saturated Hydrocarbons)

- Methane (CH_4): Flash point: -188°C (-306°F); Explosive limits (LEL/UEL): 5% to 15% by volume in air.
- Hexane (C_6H_{14}): Flash point: -22°C (-7.6°F); Vapour pressure: 17.6 kPa at 20°C; Occupational exposure limit: OSHA PEL is 500 ppm (TWA).

Alkenes (Unsaturated Hydrocarbons)

- Ethylene (C_2H_4): Vapour pressure: 5.29 MPa (at 21°C); Occupational exposure limit: OSHA PEL for ethylene is 200 ppm (TWA).

Alkynes (Unsaturated Hydrocarbons)

- Acetylene (C_2H_2): Flash point: Extremely flammable, can ignite spontaneously under pressure in air; Explosive limits: 2.5% to 100% by volume in air.

Aromatic Hydrocarbons

- Toluene ($C_6H_5CH_3$): Flash point: 4.4°C (40°F); Vapour pressure: 3.79 kPa at 20°C; OSHA PEL: 200 ppm (TWA), NIOSH REL: 100 ppm (TWA), ACGIH TLV: 20 ppm (TWA).

Key relevant UN convention / multilateral treaty

International Labour Organization (ILO), The Benzene Convention, 1971 (ILO, 1971).

World Health Organization (WHO), The International Health Regulations 2005 (WHO, 2008).

European Union REACH Regulation: The Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) regulation in the European Union addresses the safe use of chemicals, including strong acids, and imposes requirements on their registration, evaluation, and authorization. (EUR-Lex, 2023)

United Nations Climate Change (UNCC), The Kyoto Protocol and Paris Agreement on Climate Change (UNCC, 2024).

United Nations Environment Programme (UNEP), Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (UNEP, 2011).

United Nations Environment Programme (UNEP), Rotterdam Convention on the Prior Informed Consent (PIC) Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (UNEP, 2010).

United Nations Environment Programme (UNEP), Stockholm Convention on Persistent Organic Pollutants (POPs) (UNEP, 2019).

Preliminary – Corrections Pending

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Benzene is a key building block in the production of various chemicals, including styrene, phenol, aniline, nylon, and rubber. Similarly, hydrocarbons such as methane, ethane, propane, and butane are crucial for energy production, heating, and chemical synthesis. Hydrocarbons like gasoline, diesel, and natural gas are primary energy sources for transportation, power generation, and industrial operations. Benzene and other hydrocarbons are used in paints, adhesives, detergents, and as solvents in industries such as pharmaceuticals and printing. Exposure is driven by leaks and spills from tanks and storage facilities.

As economies grow, particularly in emerging markets, the demand for energy, transportation fuels, and petrochemical products increases. Hydrocarbons play a critical role in meeting this demand. Expansion of urban centres and industries drives the demand for construction materials (plastics, polymers), energy for transportation, and heating fuels, leading to increased use of hydrocarbons and benzene derivatives.

Benzene and other hydrocarbons are economically attractive because they are cost-effective and have high energy content. Finding affordable, scalable, and safe alternatives to replace these substances in various industrial processes is challenging, prolonging their use.

Impacts: Acute occupational exposure to benzene may cause narcosis: headache, dizziness, drowsiness, confusion, tremors and loss of consciousness (consumption of alcohol enhances the toxic effect). It is also irritating to the eyes, skin and respiratory tract (WHO, 2019).

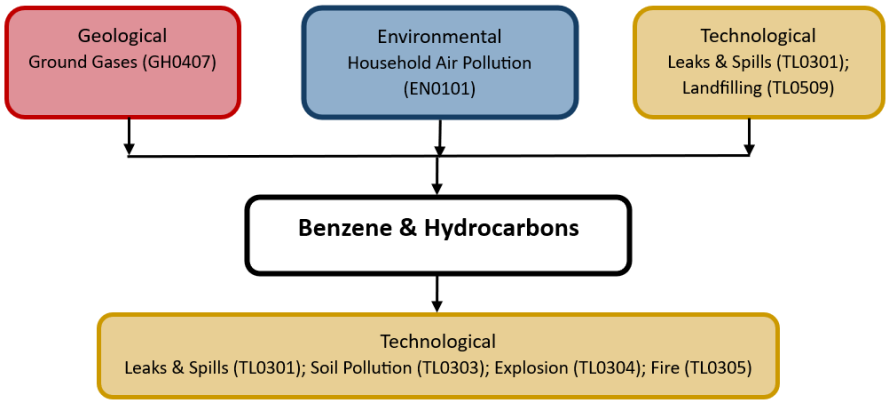
Benzene is a well-established cause of cancer in humans. The International Agency for Research on Cancer (IARC) has classified benzene as carcinogenic to humans (Group 1). The evidence in humans is considered sufficient for acute non-lymphocytic leukaemia, including acute myeloid leukaemia, while the evidence in humans is limited for non-Hodgkin lymphoma, chronic lymphoid leukaemia, multiple myeloma, chronic myeloid leukaemia, acute myeloid leukaemia in children, and lung cancer (WHO, 2019).

Oil spills are a huge concern and have major environmental and economic effects:

- **Short-Term Effects**: Immediate toxicity to marine organisms, smothering of wildlife, and destruction of habitats.
- **Long-Term Effects**: Persistent contamination of sediments and bioaccumulation of hydrocarbons in the food chain.
- **Economic Impacts**: Losses in fisheries, tourism, and clean-up costs, often amounting to billions of dollars.
- **Climate Interactions**: Oil spills exacerbate greenhouse gas emissions through methane release and contribute to global warming.

The largest oil spill occurred on 20th April 2010 on the Gulf of Mexico when the Deepwater Horizon drilling rig operated by BP exploded, killing 11 people and releasing approximately 134 million gallons of crude oil. This spill caused widespread damage to coral reefs and loss of marine biodiversity. Populations of fish, shrimp, and oysters declined sharply. Over 100,000 birds, dolphins, and other marine mammals died due to oil exposure and ingestion. Long-term effects include persistent contamination in marshes and seabed sediments, as well as mutations and reproductive issues in marine species like fish and crabs. (NOAA, 2020). There have been many other large oil spills throughout history, including the Exxon Valdez Oil Spill of 1989; the Amoco Cadiz Oil Spill of 1978; the Prestige Oil Spill of 2002; the Torrey Canyon Oil Spill of 1967; and many more. Preventing oil spills requires a combination of improved technology, strict regulation, effective monitoring, and stakeholder collaboration. Ongoing advancements in ship design, real-time monitoring systems, and offshore safety measures are essential to reducing the risk of spills and mitigating their impact when they occur.

Multi-hazard Context: The figure below summarises common interactions between benzene & hydrocarbons and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Preliminary – Corrections Pending

Monitoring: The section and the table below offer an overview of monitoring benzene & hydrocarbons. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Environmental agencies; industry regulatory bodies
How is the Hazard Observed/Monitored/ Forecast?	Air quality monitoring systems; leak detection systems; water, soil and marine monitoring systems

Risk Management: The WHO factsheet on Preventing disease through healthy environments - exposure to Benzene: a major public health concern (WHO, 2019) includes the following risk mitigation recommendations:

- Promote the use of alternative solvents in industrial processes, glues and paints.
- Develop and implement policies and legislation to remove benzene from consumer products.
- Reduce exposure at petrol filling stations as far as possible by following best practice in location, design and extraction.
- Regulatory compliance, advanced technologies, operational safety, and emergency preparedness are critical to ensuring safe and sustainable fuel transport.
- Minimise emissions from vehicle exhausts by improved design and regular monitoring of engine settings.
- Separate dwelling spaces from areas where vehicles and benzene-containing products are kept. In particular, isolate children from indoor exposure to vehicle emissions.
- Avoid domestic use of benzene-containing products.
- Discourage indoor use of unflued oil and gasoline heating.
- Implement the WHO Framework Convention on Tobacco Control (WHO, 2003), including providing for protection from exposure to tobacco smoke in indoor workplaces, public transport, indoor public places, and, as appropriate, other public places.
- Raise public awareness regarding sources of exposure to benzene, especially exposure through smoking, and awareness of risk mitigation measures.
- Conduct educational activities to discourage the use of benzene or petrol for cleaning and degreasing in industry, including in the informal sector.

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Coordinating agency or organisation

International Union of Pure and Applied Chemistry (IUPAC)

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CH0300 / CHEMICAL / Toxic Gases

Toxic Gases

Definition

Toxic gases are substances in the gaseous state that cause hazardous physiological effects when inhaled, affecting the respiratory, cardiovascular, and nervous systems, making them major public hazards (WHO 2000).

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Annotations

GHS Classification (UNECE, 2023)

Synonyms

Poisonous gases; hazardous gases; noxious gases; toxic vapours; chemical fumes; pollutant gases.
(Cross Ref. HIP CH0400 Asphyxiant Gases)

Additional scientific description

Toxic gases work by complex mechanisms. Some toxic gases are naturally occurring, while others are produced as byproducts of industrial processes, combustion, or chemical reactions. Toxic gases include some that are naturally occurring ground gases released from magma in the ground, an example being radon. Polluted air is defined as air which contains gases and particles emitted to the atmosphere by a variety of human activities and natural sources or formed in the atmosphere. At critical levels, toxic gases have harmful effects on human health, animals, plants and ecosystems, or reduce visibility and corrode materials, buildings and cultural heritage sites (HIPs EN0101-EN0103). This polluted air is mainly composed of particulate matter, ground-level ozone (O_3) and nitrogen dioxide (NO_2).

Properties of toxic gases include their volatility, density and reactivity. Many toxic gases are highly volatile, meaning they can easily vaporise and spread through the air. Their density can affect their behaviour, for example, a gas heavier than air settles in low-lying areas, while lighter gases rise. Toxic gases can also be highly reactive and can form more harmful compounds when they interact with other substances or environmental elements. They can also be naturally occurring, or produced as byproducts of industrial processes, combustion, or chemical reactions. (ATSDR, 2024; EPA, 2024; NIOSH, 2020; WHO, 2000) The different classifications and examples include:

- Respiratory irritants: These gases destroy the mucosal barrier and produce inflammatory changes leading to a damaged

respiratory tract. Examples are ammonia (HIP CH0301; ICSC 0414), chlorine (HIP CH0303; ICSC 0126), formaldehyde (ICSC 0275), hydrogen sulphide (ICSC 0165), methyl bromide (ICSC 0109), methyl isocyanate (ICSC 0004), phosgene (ICSC 0007) and sulphur dioxide (ICSC 0074).

- Systemic/chemical asphyxiants: Inhaling these gases at high concentrations acts by displacing or excluding oxygen. They have specialised mechanisms, such as combining with haemoglobin or inhibiting cytochrome C oxidase, causing inhibition of cell oxygen utilisation resulting in histotoxic anoxia, which causes significant systemic toxicity. Examples are carbon monoxide (HIP CH0302; ICSC 0023), carbon disulfide (ICSC 0022) and hydrogen cyanide (ICSC 0494).
- Volatile compounds: Once absorbed, these compounds have little or no irritant effect; they act like anaesthetic agents, or they may exhibit toxicity towards the liver, kidneys, etc. Examples are anaesthetic gases; aliphatic, aromatic and halogenated hydrocarbon gases.

Metrics and numeric limits

Limits for air contaminants (OSHA, 2013; OSHA, 2017a, b; OSHA, 2021):

- Chlorine:1 ppm; 3 mg/m^3
- Hydrogen cyanide: 10 ppm; 11 mg/m^3
- Methyl bromide: 20 ppm; 80 mg/m^3
- Methyl isocyanate: 0.02 ppm; 0.05 mg/m^3
- Phosgene: 0.05 ppm
- Sulphur dioxide: 5 ppm; 13 mg/m^3

8-hour time weighted average:

- Formaldehyde: 0.5 ppm
- Phosphene: 0.3 ppm (0.4 mg/m^3)

Acceptable ceiling concentration:

- Hydrogen sulphide: 20 ppm

Key relevant UN convention / multilateral treaty

Organisation for the Prohibition of Chemical Weapons (OPCW), Chemical Weapons Convention (OPCW, 2024a,b).

United Nations Environment Programme (UNEP), Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (UNEP, 2011).

United Nations Environment Programme (UNEP), Rotterdam Convention on the Prior Informed Consent (PIC) Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (UNEP, 2010).

United Nations Environment Programme (UNEP), Stockholm Convention on Persistent Organic Pollutants (POPs) (UNEP, 2019).

World Health Organization (WHO), International Health Regulations (WHO, 2016).

World Health Organization (WHO), Environmental Health Criterion (WHO, 1981).

Examples of hazard drivers, impacts and risk management

Hazard Drivers: In industry, chemical manufacturing processes often use gases during production and can release gases such as carbon dioxide. The Dakar Ammonia Accident in 1992, where ammonia was used to detoxify the peanut oil product, involved a pressurised overfilled, poorly repaired ammonia tank which failed releasing 22 tonnes of ammonia. In this incident, there were 129 lives lost, with 1,150 other workers and citizens injured.

Another driver of toxic gases is their transportation, which can lead to accidental releases, particularly in the case of chemical spills or accidents involving tankers. Agricultural practices and waste management can also drive the release of toxic gases, such as ammonia and hydrogen sulphide from certain pesticides and fertilisers, and improper handling and disposal of hazardous wastes, leading to environmental contamination and human exposure. (EPA, 2024; NIOSH, 2020; WHO, 2000)

Some toxic gases are naturally occurring and can be released or created upon natural disasters, such as volcanic eruptions, wildfires, and certain geological formations. Examples of natural disasters include limnic eruptions, where dissolved carbon dioxide suddenly erupts from the deep waters of lakes. Carbon monoxide is also often released during power outages, including load shedding. (CDC, 2024)

Impacts of toxic gases include human health effects from inhalation; harm to ecosystems, soil quality, water quality and biodiversity, leading to long-term environmental degradation; economic losses due to cleanup and remediation efforts, healthcare expenses, property damage, and loss of productivity; and evacuations causing displacement of communities and social unrest. (EPA, 2024;

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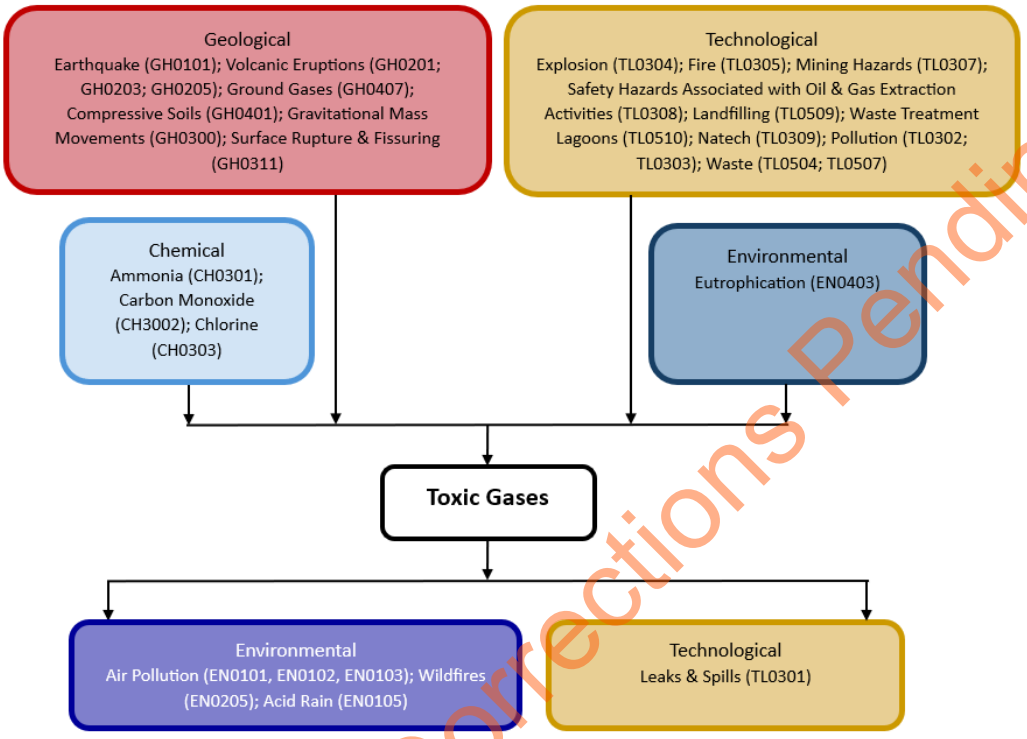
NIOSH, 2020; WHO, 2000)

Multi-hazard Context: The figure below summarises common interactions between toxic gases and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring toxic gases. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Depending on the source of the gases, national geological agencies, private compa management services
How is the Hazard Observed/Monitored/Forec	Detectors and sensors, communication systems, monitoring and control centres

Risk Management strategies include implementing engineering work to minimise toxic gas generation and release. Air quality monitoring systems and gas detection technologies can be used to detect and respond to toxic gas leaks or releases promptly. Also, developing emergency response plans, conducting drills, and providing training to personnel can mitigate impacts the of incidents. Reporting of emissions and releases is vital for adhering to regulatory requirements and standards. Educating the public about the risks and encouraging community engagement in pollution prevention efforts can minimise the risks associated of toxic gases. (EPA, 2024; NIOSH, 2020; WHO, 2000)

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Coordinating agency or organisation

International Union of Pure and Applied Chemistry (IUPAC)

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CH0301 / CHEMICAL / Toxic Gases

Ammonia

Definition

Ammonia (NH_3) is a colourless acrid-smelling reactive gas at ambient temperature and pressure and is considered a significant public health hazard (WHO, 1986; PHE, 2019).

References

WHO, 1986. Environmental Health Criteria 54: Ammonia. 10.4, Accidental exposure. International Programme on Chemical Safety, World Health Organization (WHO). www.inchem.org/documents/ehc/ehc/ehc54.htm#SectionNumber:10.4 Accessed 19 July 2024.

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Annotations

GHS Classification

Synonyms

NH_3, Anhydrous ammonia, Ammonia gas, Spirit of hartshorn, Azane.

Additional scientific description

Ammonia is a colourless, non-flammable gas, but is treated as flammable because it can form explosive mixtures with air. Ammonia dissolves readily in water. Solutions of ammonia are alkaline and can be corrosive when concentrated or mixed with water. In addition to irritation symptoms, delayed onset of serious respiratory symptoms may present, including corrosive damage to the mucous membranes of both the upper and lower respiratory tract (WHO, 1986; PHE, England 2019).

Ammonia is lighter than air, so the vapours from a leak will initially hug the ground. Long-term exposure to low concentrations or short-term exposure to high concentrations may result in adverse health conditions from inhalation. Prolonged exposure of containers to fire or heat may result in their violent rupturing and rocketing. Both liquid and vapours are extremely irritating, especially to the eyes (Cameo Chemicals, no date).

Ammonia is an extensively used industrial chemical. It is commonly used in the production of fertilisers, fibres and plastics, and explosives; as a cleaning and descaling agent, in food additives, and as industrial refrigerant (WHO, 1986).

High gaseous ammonia concentrations may be encountered locally, both in domestic and occupational environments, as a result of gaseous emissions and/or spillages of concentrated solutions. This can cause respiratory, skin or eye injury. On a larger scale, spillage from stock or transport tanks or refrigeration plants of

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concentrated ammonia liquor or anhydrous ammonia would constitute severe environmental damage and would cause serious injury to people, animals, and plants in the vicinity. Owing to its low density and short bio-persistence, major spillages would be expected to disperse rapidly and not to persist in the environment (WHO, 1990).

Ammonia can be stored and transported as a liquid at a pressure of 10 atm at 25°C. Ammonia dissolves readily in water where it forms, and is in equilibrium with ammonium ions (NH_4^+). The sum of ammonia and ammonium concentrations is termed 'total ammonia' and, owing to the slightly different relative molecular masses, may be expressed as 'total ammonia-nitrogen (NH_3-N)'. In most waters, NH_4^+ predominates, but increased pH or temperature or decreased ionic strength may materially increase levels of non-ionized ammonia (WHO, 1986).

Metrics and numeric limits

Drinking water: There is no health-based standard proposed by the World Health Organization (WHO) for ammonia in drinking water. This is because the odour threshold (1.5 mg/L) and taste threshold (35 mg/L) are considered to be below levels of health concern (WHO, 2011). However, ammonia has the potential to reduce the effectiveness of some water treatment techniques, and so some countries do prescribe a guideline value.

Air: There are no air quality guidelines for ambient levels of ammonia and public health. However, individual countries may develop occupational exposure limits and adopt acute/emergency guidelines.

On the other hand, guidelines do exist for ammonia and its health risks associated with larger releases of ammonia in accident scenarios. See for example: Emergency Response Planning Guidelines (ERPG) (NOAA, 2016) and Acute Exposure Guideline Levels for Airborne Chemicals (AEGLs) (US EPA, 2024).

Key relevant UN convention / multilateral treaty

United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (UNECE, 2024).

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Industrial refrigeration systems that use ammonia as a refrigerant can pose risks of ammonia leaks if not properly maintained or operated. Accidental releases of ammonia gas from refrigeration systems have led to evacuations, injuries, and fatalities in workplaces such as food processing facilities, cold storage warehouses, and ice rinks.

Ammonia is transported in bulk quantities by rail, tanker trucks, and pipelines for various industrial applications. Accidents involving derailments, collisions, or leaks during transportation or use can result in the release of ammonia gas into the environment. These incidents pose risks to nearby communities and emergency responders, who may be exposed to the toxic gas (US DOT, 2024).

Impacts: Breathing in low levels of ammonia may cause irritation to the eyes, nose and throat. High levels of ammonia may cause burns and swelling in the airways, lung damage and can be fatal. Ingestion of ammonia solutions can cause pain and burns throughout the digestive tract. In severe cases, the respiratory system, stomach and heart may be damaged, and death may follow. Strong ammonia solutions may cause serious burns if splashed on the skin. At high concentrations, gases and fumes of ammonia can also cause corrosive damage to the skin. Splashes in the eye may cause damage that may be irreversible in some cases and can lead to loss of sight. The health effects of ammonia are usually immediate, and long-term effects would not be expected after exposure to small amounts (PHE, 2019).

Anhydrous ammonia (liquid or gas) reacts with tissue water to form the corrosive solution ammonium hydroxide. Following body surface exposure, it is advised to disrobe, and improvised wet decontamination should be considered. Spillages and decontamination run-off should be prevented from entering watercourses (PHE, 2019).

Atmospheric ammonia can damage plant foliage when the rate of foliar uptake exceeds the rate at which the plant can detoxify ammonia. High levels of ammonia can affect plant growth and productivity, drought/frost tolerance, and plant response to insect pests and disease (Krupa 2003).

Multi-hazard Context: The figure below summarises common interactions between ammonia and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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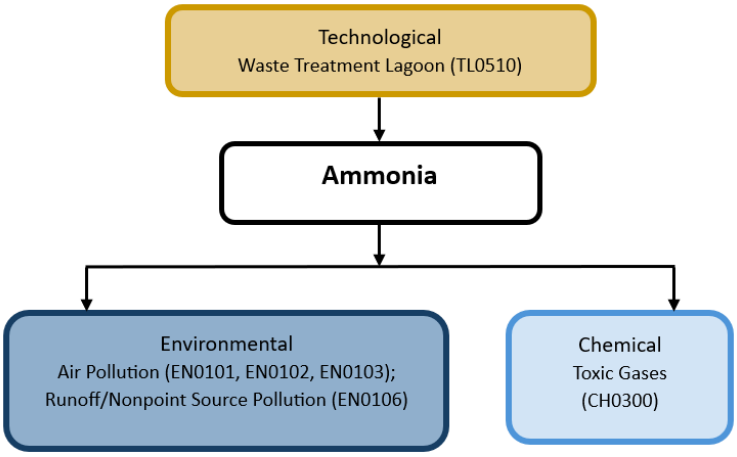

Monitoring: The section and the table below offer an overview of monitoring ammonia. This information can be do the same for this one, ISC style guide, give me a list only of things I need to change used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	World Health Organization (WHO) United Nations Environment Programme (UNEP) Environmental Protection Agency (EPA) Occupational Safety and Health Administration (OSHA).
How is the Hazard Observed/Monitored/Forecast?	Advanced monitoring sensors (both fixed and portable) to detect ammonia levels

Risk Management: Documented accidents underscore the importance of proper handling, storage, and transportation of ammonia, as well as emergency preparedness and response measures, to prevent and mitigate the impacts of ammonia-related incidents on public health and safety.

- Consider evacuation where spillage or leakage has occurred.
- Improvised wet decontamination should be considered in the case of skin contamination, as ammonia reacts with tissue water to form the corrosive solution ammonium hydroxide (PHE, 2019).
- Spillages and decontamination run-off should be prevented from entering watercourses (PHE, 2019) due to potential damage to plants and animals.
- Encourage the avoidance of agricultural land during the use of ammonia fertilisers (ATSDR, 2004).
- Harmonised labelling and transport approaches should be considered.

An early warning system for ammonia contamination is essential for promptly detecting and mitigating the risks associated with ammonia releases. These systems typically include advanced monitoring sensors (both fixed and portable) to detect ammonia levels in real-time. They employ technologies such as electrochemical and infrared sensors to provide accurate measurements. Data from these sensors is analysed and integrated into centralized systems that trigger audible, visual, and remote alerts when ammonia levels exceed safe thresholds. These alerts enable rapid response, ensuring the safety of personnel and minimizing environmental impact. By incorporating predefined response protocols, early warning systems for ammonia contamination help industries, agricultural operations, and wastewater treatment facilities prevent harmful exposure, comply with safety regulations, and protect public health and the environment.

- World Health Organization (WHO): Establishes health-based guidelines for ammonia exposure.
- United Nations Environment Programme (UNEP): Supports global initiatives for pollution monitoring and early warning systems.
- Environmental Protection Agency (EPA): Provides guidelines and regulations for ammonia monitoring and control. Supports the development of early warning systems through research and funding.
- Occupational Safety and Health Administration (OSHA). Sets permissible exposure limits (PELs) for ammonia in the workplace. Enforces regulations for ammonia monitoring and safety protocols.

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Coordinating agency or organisation

World Health Organization (WHO)

International Union of Pure and Applied Chemistry (IUPAC)

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CH0302 / CHEMICAL / Toxic Gases

Carbon Monoxide

Definition

Carbon monoxide is a colourless, odourless gas that can be poisonous to humans and is considered a significant public health hazard (WHO, 1999).

Reference

WHO, 1999. Environmental Health Criteria 213: Carbon monoxide. Second Edition. International Programme on Chemical Safety, World Health Organization (WHO). https://www.who.int/publications/i/item/9241540737 Accessed 11 May 2024.

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Annotations

GHS Classification

Synonyms

CO, CO gas, Carbon monoxide gas, Carbonic oxide, Carbon (II) oxide, Flue gas (when referring to exhaust gases from combustion), Exhaust gas (specifically from engines and combustion processes)

Additional scientific description

Carbon monoxide (CO) is one of the most common and widely distributed air pollutants. It is a colourless, odourless and tasteless gas that is poorly soluble in water. Carbon monoxide has a slightly lower density than air. In the human body, it reacts readily with haemoglobin to form carboxyhaemoglobin. Small amounts of carbon monoxide are also produced endogenously. Carbon monoxide exposure is still one of the leading causes of unintentional and suicidal poisonings and causes a large number of deaths annually (WHO, 2000).

It is a product of the incomplete combustion of carbon-containing fuels and is also produced by natural processes or by biotransformation of halomethanes within the human body (Anders, 1985). With external exposure to additional carbon monoxide, subtle effects can begin to occur, and exposure to higher levels can result in serious symptoms and death. The health effects of carbon monoxide are largely the result of the formation of carboxyhaemoglobin (COHb), which impairs the oxygen-carrying capacity of the blood (WHO, 1999).

The total annual global emissions of carbon monoxide into the atmosphere have been estimated to be as high as 2600 million tonnes, of which about 60% are from human activities and about 40% from natural processes such as wildfires. Anthropogenic emissions of carbon monoxide originate mainly from the incomplete combustion of carbonaceous materials. The largest proportion of these emissions is produced as exhaust gases from internal combustion engines, especially by motor vehicles with petrol engines. Other common sources include various industrial processes, power plants using coal, and waste incinerators.

Petroleum-derived emissions have greatly increased over the past few decades. Some widespread natural non-biological and biological sources, such as plants, oceans and oxidation of hydrocarbons, give rise to the background concentrations outside urban areas. In indoor environments, space heaters fuelled with oil, gas or kerosene, gas stoves and some other combustion

appliances (e.g., wood stoves), and tobacco smoking are also responsible for significant emissions of carbon monoxide (WHO, 2000).

Metrics and numeric limits

Indoor air: 100 mg/m3 (87 ppm) for 15 minutes, 35 mg/m3 (30 ppm) for 1 hour, 10 mg/m3 (8.7 ppm) for 8 hours, 7 mg/m3 (6.1 ppm) for 24 hours (WHO, 2010).

Emergency response and acute exposure: Emergency Response Planning Guidelines (ERPG) (NOAA, 2016) and Acute Exposure Guideline Values for Airborne Chemicals (AEGLs) (US EPA, no date) exist for carbon monoxide.

Key relevant UN convention / multilateral treaty

United Nations Framework Convention on Climate Change (UNFCCC). Carbon monoxide, as a product of incomplete combustion, is relevant because its emissions are often associated with the burning of fossil fuels, which also produce carbon dioxide (CO2), a major greenhouse gas.

Stockholm Convention on Persistent Organic Pollutants (POPs). While carbon monoxide is not a persistent organic pollutant, the Stockholm Convention addresses the broader issue of air quality and the reduction of harmful chemicals released into the atmosphere.

Convention on Long-Range Transboundary Air Pollution (CLRTAP). This convention specifically aims to reduce and prevent air pollution, including carbon monoxide, which can travel long distances across borders.

World Health Organization (WHO) Air Quality Guidelines. The WHO provides global guidelines for air quality, including specific recommendations for acceptable levels of carbon monoxide exposure to protect human health.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers. Carbon monoxide is produced when fossil fuels burn without enough oxygen. The most important source of exposure to carbon monoxide for the general public is from cooking or other fuel-burning appliances which are poorly installed, faulty or used inappropriately (including inadequate ventilation).

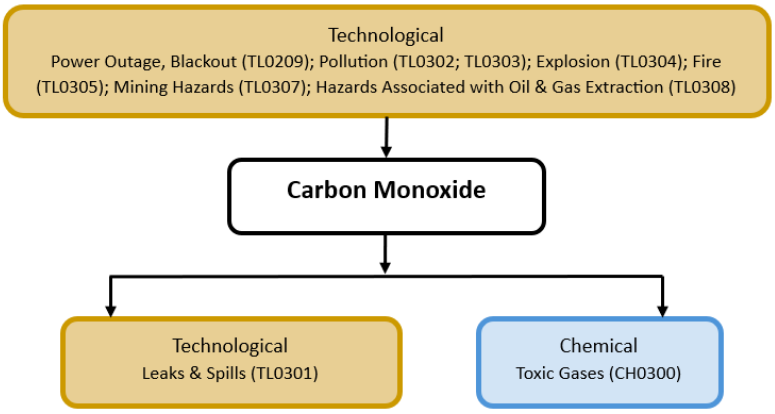
Carbon monoxide can be related to: (1) Natural hazards: Example: Wildfires and forest fires can produce large amounts of carbon monoxide due to incomplete combustion of organic material. (2) Industrial Processes: Example: Industrial accidents, such as explosions or fires at manufacturing plants or refineries, can release significant quantities of carbon monoxide. (3) Urban Environments: Example: Heavy traffic and poorly ventilated urban areas can have high concentrations of carbon monoxide from vehicle exhaust. (4) Residential Heating and Cooking: Example: Improperly vented or malfunctioning heating systems and cooking appliances can produce dangerous levels of carbon monoxide indoors. (5) Climate Change: Example: Increased temperatures and altered weather patterns can influence the frequency and intensity of wildfires, thereby increasing carbon monoxide emissions.

Impacts. An example of the impacts of carbon monoxide contamination includes home boilers that are installed incorrectly, and the use of BBQs and portable generators inside homes, caravans and tents. Inhaling smoke from a house fire may lead to carbon monoxide exposure. For smokers, cigarettes are the major source of carbon monoxide. Use of shisha/hookah pipes may also lead to exposure. Exposure to low levels of carbon monoxide can occur outdoors, as it is produced by vehicle exhausts and industrial processes (PHE, 2019).

In emergency situations where power is lost, using an improperly vented generator inside a home or building, or using gas grills, charcoal grills, or hibachis indoors can lead to dangerous levels of carbon monoxide. Breathing high levels of carbon monoxide can be fatal. Breathing lower levels of carbon monoxide can permanently harm the heart and brain. Carbon monoxide tends to be more harmful to people with heart or lung disease (ATSDR, 2012). Similarly, the use of generators after meteorological and hydrological hazards such as gale, squall, storms and cyclones, can lead to dangerous levels of carbon monoxide.

Multi-hazard Context: The figure below summarises common interactions between carbon monoxide and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

Preliminary – Corrections Pending



Monitoring: The section and the table below offer an overview of monitoring carbon monoxide. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disast Risk Data/Information?	World Health Organization (WHO)
How is the Hazard Observed/Monitored/Forecast?	Detection and monitoring technologies such as CO detectors, environmental surveillance from fixed and mobile monitoring stations, and public health notifications using alert systems.

Risk Management: Measures to limit impacts of carbon monoxide exposure include:

- Encourage means to reduce exposure in the home and indoor environment by discouraging the use of solid fuels, such as charcoal and biomass and encouraging cooking in well-ventilated spaces.
- Educate emergency services, volunteers and others to eliminate the use of generators in confined spaces where people may be exposed. This is particularly relevant during emergency and disaster response and recovery activities where main power supplies are lost.
- Public awareness campaigns contribute to the prevention of carbon monoxide poisoning in residential contexts.
- Consider regulating for safe installation of indoor heating appliances.
- Separate dwelling spaces from vehicle garages.
- Discourage the indoor running of combustion engine vehicles or require adequate ventilation where this is not possible.
- Avoid cigarette smoke and smoking (particularly pregnant women and children) as these are a source of carbon monoxide (and other hazardous chemicals).

Examples of early warning systems include detection and monitoring technologies such as CO detectors, environmental surveillance from fixed and mobile monitoring stations, and public health notifications using alert systems.

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Coordinating agency or organisation

World Health Organization (WHO).

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0303 / CHEMICAL / Toxic Gases

Chlorine

Definition

Chlorine is a reactive pale green gas with many uses, including disinfection of water. Chlorine is approximately 2.4 times heavier than air and has a characteristic odour similar to bleach. Most significant exposures to chlorine result from loss of containment of chlorine during storage and transport. Human exposure can result in symptoms ranging from mild irritation to rapid death related to pulmonary oedema. It is considered a significant public health hazard (adapted from IPCS, 1982 and PHE, 2019).

Preliminary – Corrections Pending

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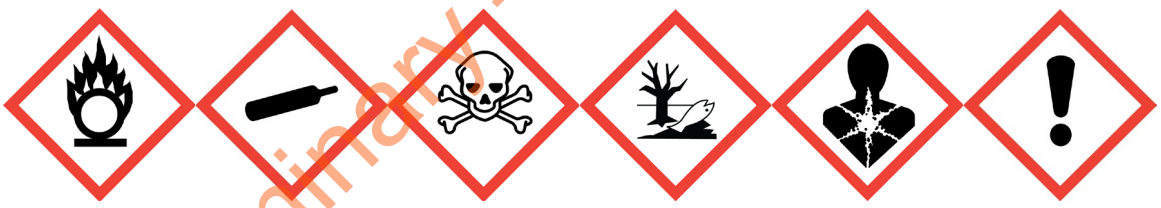
Annotations

GHS Classification (UNECE, 2023)



Synonyms

Cl_2, Chlor, Dichlorine, Bertholite, Molecular chlorine, Elemental chlorine, Chlorine gas, UN 1017 (for shipping and transport).

Additional scientific description

Chlorine (chemical symbol Cl, atomic number 17) reacts violently with bases and is a corrosive, strong oxidant. It also reacts violently with combustible substances and reducing agents and most organic and inorganic compounds, causing a fire and explosion hazard. It may also combine with water or steam to produce toxic and corrosive fumes of hydrochloric acid (PHE, 2019). During fires involving chlorine and carbon-containing materials, the formation of phosgene–a highly toxic pulmonary agent–may occur, representing an additional risk to emergency responders (Vaish, 2013).

Chlorine is used in the disinfection of water and in the production of bleach and chlorinated hydrocarbon solvents, polyvinyl chloride and other industrial processes. Large quantities are also used in the bleaching of pulp and paper.

Bleach contains sodium hypochlorite, which, if (inadvertently) mixed with acidic chemicals, can result in the generation and release of chlorine gas. If chlorine is released from a tank into the air, the chlorine will evaporate very quickly, forming a highly toxic greenish-yellow cloud (ATSDR, 2010). Due to its relatively low boiling point and high density compared to air, chlorine gas tends to settle in low-lying and enclosed areas, increasing the risk of accumulation and exposure in confined spaces.

Metrics and numeric limits

Drinking water: 5 mg/L (WHO, 2011).

Emergency response and acute exposure: there are Emergency Response Planning Guidelines (ERPG) (NOAA, 2016) and Acute Exposure Guideline Values for Airborne Chemicals (AEGLs) (US EPA, 2004) as a result of health risks associated with releases and spills of chlorine.

Key relevant UN convention / multilateral treaty

World Health Organization (WHO) International Health Regulations (WHO, 2016).

Organisation for the Prohibition of Chemical Weapons (OPCW), Chemical Weapons Convention. (OPCW, 2024a; b)

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Chlorine contamination is caused by anthropogenic activities that include accidents or misuse in industrial and similar settings, leading to significant health and environmental impacts.

Documented accidents involving chlorine, a highly reactive and toxic gas, have occurred in various industries and settings, leading to significant health and environmental impacts. Chlorine can be related to: (1) Industrial Accidents, (2) Natural hazards, (3) Urban Environments, (4) Terrorism and Sabotage, (5) Transport and Storage.

Chlorine Release Accidents in Chemical Plants:

Accidental releases of chlorine gas can occur in chemical manufacturing facilities, particularly those involved in the production of chlorinated chemicals such as PVC (polyvinyl chloride) and chlorine bleach. Chlorine gas is highly toxic and can cause respiratory irritation, lung damage, and even death at high concentrations (CDC, 2023 - https://emergency.cdc.gov/agent/chlorine/basics/facts.asp).

Chlorine is transported in railcars and tanker trucks for various industrial applications. Accidents involving derailments, collisions, or leaks during transportation can result in the release of chlorine gas into the environment. These incidents pose risks to nearby communities and emergency responders, who may be exposed to the toxic gas (USDT PHMSA, 2024, UK HSA, 2024).

Chlorine is commonly used in water treatment facilities to disinfect drinking water supplies. Accidental over-chlorination or equipment failures can lead to the release of excess chlorine into the water distribution system, resulting in elevated chlorine levels in drinking water and potential health risks for consumers. These documented accidents underscore the importance of proper handling, storage, and transportation of chlorine, as well as emergency preparedness and response measures, to prevent and mitigate the impacts of chlorine-related incidents on public health and safety.

Impacts: Minor exposures to chlorine may result in a burning sensation of the eyes and throat. More substantial exposure may cause coughing or breathing difficulties. Exposure to high concentrations of chlorine gas can damage the lungs and airways, hours after the exposure, potentially without preceding warning symptoms; this may cause a build-up of fluid in the lungs (oedema), which can be fatal. Following severe injuries from inhaling chlorine, there may be shock, coma, and death, or when surviving, a chronic disorder of the lungs. Those exposed during physical exertion appear especially vulnerable (IPCS, 1982; PHE, 2019).

Owing to its hazardous nature, the majority of chlorine is transported by rail (ILO, 2004).

The modern use of chemical weapons began with World War I, when both sides in the conflict used poisonous gas to inflict agonising suffering and cause significant battlefield casualties. Such weapons basically consisted of well-known commercial chemicals put into standard munitions such as grenades and artillery shells. Chlorine was a common chemical used in this way historically and still presents a risk (United Nations Office for Disarmament Affairs, no date; OPCW, 2024a; b; c).

Multi-hazard Context: The figure below summarises common interactions between chlorine and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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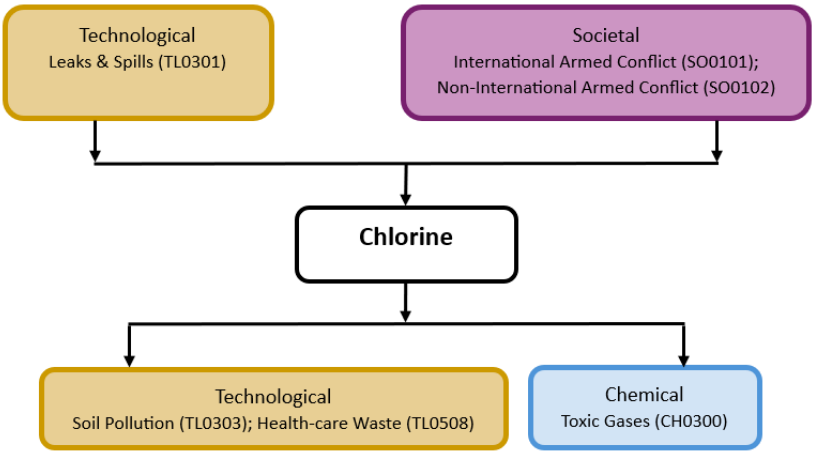

Monitoring: The section and the table below offer an overview of monitoring chlorine. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster R Data/Information?	World Health Organization (WHO) Organization for the Prohibition of Chemical Weapons (OPCW), National terrc agencies
How is the Hazard Observed/Monitored/Forecast?	Sensors, monitoring networks; response protocols, portable gas detectors

Risk Management. Spillages and run-off should be prevented from entering watercourses as chlorine is harmful to the natural environment; evacuation should be considered in a written emergency plan for significant spills and leaks of chlorine such as from tanks; and harmonised labelling and transport approaches should be adhered to.

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Coordinating agency or organisation

Organization for the Prohibition of Chemical Weapons (OPCW).

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0400 / CHEMICAL / Asphyxiant Gases

Asphyxiant Gases

Definition

Asphyxiant gases are gases that can cause unconsciousness or death by suffocation by displacing oxygen from the air. Asphyxiant gases that have no other health effects are considered simple asphyxiants. Simple asphyxiant gases become harmful to humans at high concentrations by lowering the percentage of oxygen in air (regularly present at 21%) to 19.5% or lower. (CCOHS, 2024)

Preliminary – Corrections Pending

References

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Annotations

GHS Classification (UNECE, 2023)

Synonyms

Suffocant, Choking agent, Asphyxiating substance, Inert gas hazard, Oxygen-deficient atmosphere, Oxygen displacer, Smothering agent

Additional scientific description

Many asphyxiant gases are stored in and used from compressed gas cylinders or tanks. Large amounts, stored at high pressure, can displace air (and its oxygen) if it is released (accidentally or deliberately). (Cross Ref. GH0027 Ground Gases (CH4, Rn, etc.).

Examples of simple asphyxiant gases include:

(1) Nitrogen (N_2): Nitrogen is the most common gas in the Earth's atmosphere, comprising approximately 78% of the air we breathe. While nitrogen is not toxic, it can cause asphyxiation if present in high concentrations, displacing oxygen in the air.

(2) Helium (He): Helium is an inert gas that is lighter than air. It is commonly used in balloons, airships, and for various industrial purposes. While helium itself is not toxic, it can pose an asphyxiation risk if it displaces oxygen in confined spaces.

(3) Argon (Ar): Argon is another inert gas that is heavier than air. It is often used in welding and other industrial processes. Like nitrogen and helium, argon is not toxic, but it can cause suffocation by displacing oxygen in poorly ventilated areas.

(4) Carbon Dioxide (CO_2): While carbon dioxide is typically considered a simple asphyxiant at high concentrations, it also has toxic properties at elevated levels. CO_2 is produced by combustion processes, fermentation, and respiration. In confined spaces, high levels of carbon dioxide can displace oxygen, leading to asphyxiation.

(5) Low Molecular Weight Alkanes (LMWA): Low molecular weight alkanes refer to a group of saturated hydrocarbons such as methane, ethane, propane, and butane, that have relatively small numbers of carbon atoms. Several of these gases are denser than air, so they can accumulate in low-lying areas, posing asphyxiation hazards in confined spaces. They are also highly flammable gases at room temperature and pressure, and they can form explosive mixtures with air within specific concentration ranges. When handling LMWA, it is essential to observe several precautions to ensure safety and minimize risks associated with their flammability and air-displacing properties.

(6) Methane (CH_4): Methane is a colourless, odourless, highly flammable gas that belongs to the LMWA family. It is the primary component of natural gas. In addition to being a flammable hazard, methane can also act as a simple asphyxiant in confined spaces by displacing oxygen. As with the other LMWA compounds (see above), it can form explosive mixtures with air, particularly in confined spaces.

(7) Propane (C_3H_8): Propane is a colourless, odourless, highly flammable gas that belongs to the LMWA family. Propane is commonly used as a fuel where natural gas pipelines are not available, and thus it is widely known for its practical applications in residential, commercial, and industrial settings. It has a higher density than air and can accumulate in low areas. Adequate ventilation is crucial when using propane indoors to prevent the buildup of potentially dangerous concentrations.

Inhalation of these gases in high concentrations can cause symptoms of asphyxiation, including dizziness, confusion, rapid breathing, rapid heart rate, and loss of consciousness. It's important to ensure proper ventilation in areas where these gases are present and to use appropriate safety measures to prevent asphyxiation accidents.

Metrics and numeric limits (OSHA, 2013; OSHA, 2017a; b)

1. Nitrogen (N_2):
   - Permissible Exposure Limit (PEL): OSHA sets the PEL for nitrogen at 1,000,000 parts per million (ppm) as an 8-hour time-weighted average (TWA).
   - Threshold Limit Value (TLV): ACGIH recommends a TLV of 3,000,000 ppm as an 8-hour TWA for nitrogen.
   - Short-Term Exposure Limit (STEL): NIOSH suggests a STEL of 5,000,000 ppm for nitrogen over a 15-minute period.
2. Helium (He):
   - Permissible Exposure Limit (PEL): OSHA does not currently have a specific PEL for helium due to its inert nature and low toxicity.
3. Carbon Dioxide (CO_2):
   - Permissible Exposure Limit (PEL): OSHA sets the PEL for carbon dioxide at 5,000 ppm as an 8-hour TWA.
   - Threshold Limit Value (TLV): ACGIH recommends a TLV of 5,000 ppm as an 8-hour TWA for carbon dioxide.
   - Short-Term Exposure Limit (STEL): ACGIH suggests a STEL of 15,000 ppm for carbon dioxide over a 15-minute period.
4. Argon (Ar):
   - Permissible Exposure Limit (PEL): OSHA does not currently have a specific PEL for argon due to its inert nature and low toxicity.
5. Methane (CH_4):
   - Permissible Exposure Limit (PEL): OSHA sets the PEL for methane at 1,000 ppm as an 8-hour TWA.
   - Threshold Limit Value (TLV): ACGIH recommends a TLV of 1,000 ppm as an 8-hour TWA for methane.
   - Short-Term Exposure Limit (STEL): ACGIH suggests a STEL of 5,000 ppm for methane over a 15-minute period.
6. Propane (C_3H_8):
   - The immediate dangerous to life and health (IDLH) concentration for propane is 2,100 ppm (2.1% to 9.5% by volume). This is the concentration level from which one could escape within 30 minutes without experiencing any escape-impairing or irreversible health effects.

OSHA Hazard Information Bulletins, Potential Carbon Dioxide (CO_2) Asphyxiation Hazard When Filling, Stationary Low Pressure CO_2 Supply Systems. The current OSHA standard is 5000 ppm as an 8-hour time-weighted average (TWA) concentration.

Gaseous carbon dioxide is an asphyxiant. Concentrations of 10% (100,000 ppm) or more can produce unconsciousness or death (OSHA 1996).

Key relevant UN convention / multilateral treaty

1910.101 - Compressed gases (general requirements). Standard Number: 1910.101

Preliminary – Corrections Pending

Examples of hazard drivers, impacts and risk management

Hazard Drivers. Asphyxiant gases can be released into the environment through various natural and human activities. In addition to deliberate or accidental release from cylinders or tanks of compressed gases, some examples of drivers or sources of asphyxiant gases are:

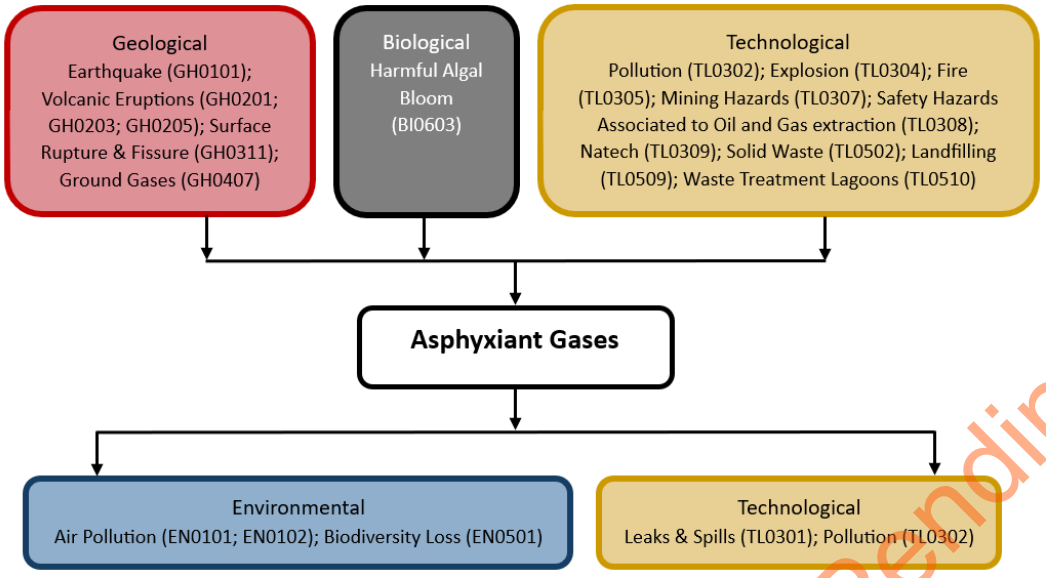
- **Industrial Processes**: Many industrial processes involve the use or production of gases that can act as simple asphyxiants. For example:(a) Welding and metal fabrication can release argon or nitrogen used as shielding gases. (b) Chemical manufacturing processes may produce or release nitrogen, argon, or carbon dioxide. (c) Refineries and petrochemical plants can release methane and other gases during extraction, processing, and storage of hydrocarbons.
- **Agricultural Activities:** Agricultural practices can generate asphyxiant gases, particularly in confined spaces such as silos and manure pits. Decomposition processes in silage and manure can produce significant amounts of carbon dioxide and methane, which can displace oxygen.
- **Mining Operations:** Mining activities, particularly in underground mines, can generate asphyxiant gases due to natural processes and the use of machinery. Methane, carbon dioxide, and nitrogen can be present in mine atmospheres, posing risks to workers if not properly controlled.
- **Confined Spaces:** Any enclosed or poorly ventilated space has the potential to accumulate asphyxiant gases. This includes: Tanks, vessels, and storage containers where inert gases like nitrogen or argon may be used or present; underground tunnels, sewers, and manholes where natural gas or other gases may accumulate; Cargo holds of ships, where gases released from cargo or fuel may displace oxygen.
- **Natural Sources:** Some natural processes can also release asphyxiant gases into the environment: Volcanic eruptions can release large quantities of carbon dioxide, sulfur dioxide, and other gases; Decomposition of organic matter in stagnant water bodies, such as swamps or ponds, can produce methane and carbon dioxide; Geological processes, such as the release of gases from underground reservoirs or faults, can contribute to local concentrations of asphyxiant gases.
- **Accidental Releases:** Accidents involving storage, transportation, or handling of gases can lead to sudden releases of asphyxiant gases. For example, leaks from pipelines, storage tanks, or industrial equipment can result in the rapid buildup of gases in the surrounding area.

Impacts: The diverse range of activities and processes that can contribute to the presence of asphyxiant gases in the environment emphasizes the importance of proper monitoring, ventilation, and safety measures to prevent asphyxiation incidents. The impact of exposure to asphyxiant gases can range from mild symptoms of oxygen deprivation to severe injury or death, depending on the concentration of the gas, the duration of exposure, and individual susceptibility. Common outcomes of exposure to high concentrations of asphyxiant gases include:

- **Mild Symptoms**: Inhaling low to moderate levels of asphyxiant gases may initially cause mild symptoms such as dizziness, headache, confusion, shortness of breath, and rapid heart rate. These symptoms can escalate with prolonged exposure or higher concentrations of the gas.
- **Loss of Consciousness:** Continued exposure to high concentrations of asphyxiant gases can lead to loss of consciousness and unconsciousness due to oxygen deprivation. This can occur relatively quickly in poorly ventilated spaces or confined areas where the gas accumulates.
- **Suffocation and Asphyxiation:** Without intervention, prolonged exposure to high concentrations of asphyxiant gases can result in suffocation and asphyxiation, leading to permanent brain damage or death.
- **Explosions and Fires:** Some asphyxiant gases, such as methane, have flammable properties. In environments where oxygen levels are depleted due to the presence of the gas, there is an increased risk of explosions or fires if an ignition source is introduced.

Multi-hazard Context: The figure below summarises common interactions between asphyxiant gases and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

Preliminary – Corrections Pending



Monitoring: The section and the table below offer an overview of monitoring asphyxiant gases. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Ris Data/Information?	Depending on the source of the gases, national geological agencies, private compa fire management services
How is the Hazard Observed/Monitored/Fo	Oxygen sensors and similar devices for other gases, or multi-gas sensors, fitted wit appropriate alarms can detect and warn of developing asphyxiant circumstances

Risk Management strategies for dealing with asphyxiant gases aim to prevent exposure and mitigate the potential consequences. Here are some key risk management measures:

- **Hazard Assessment:** Identify sources of asphyxiant gases in the workplace through thorough hazard assessments and risk evaluations. Determine the potential for exposure and assess the risks to workers and the surrounding environment.
- **Engineering Controls:** Implement engineering controls to minimize the release and accumulation of asphyxiant gases. This may include proper ventilation systems, gas detection monitors, and inerting or purging procedures in confined spaces.
- **Administrative Controls:** Develop and implement administrative controls, such as safe work practices, procedures, and training programs, to minimize the risk of exposure to asphyxiant gases. Ensure that workers are aware of the hazards and know how to respond in case of an emergency.
- **Personal Protective Equipment (PPE):** Provide appropriate personal protective equipment, such as respiratory protection, for workers who may be exposed to asphyxiant gases. Ensure that PPE is properly fitted, maintained, and used according to manufacturer guidelines and regulatory requirements.
- **Emergency Response Planning:** Develop comprehensive emergency response plans and procedures for dealing with accidental releases of asphyxiant gases. Conduct regular drills and training exercises to ensure that workers are prepared to respond effectively in case of an emergency.
- **Monitoring and Testing:** Implement routine monitoring and testing programs to assess the concentration of asphyxiant gases in the workplace and ensure that exposure levels remain below regulatory limits. Use gas detection equipment to continuously monitor air quality in areas where asphyxiant gases may be present.

By implementing these risk management strategies, employers can effectively mitigate the hazards associated with exposure to asphyxiant gases and protect the health and safety of workers in the workplace.

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Hazardous chemical means any chemical which is classified as a physical hazard or a health hazard, a simple asphyxiant, combustible dust, pyrophoric gas, or hazard not otherwise classified. https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.1200 Accessed 17 May 2024.

Simple asphyxiant means a substance or mixture that displaces oxygen in the ambient atmosphere, and can thus cause oxygen deprivation in those who are exposed, leading to unconsciousness and death.

The physical, health, simple asphyxiation, combustible dust, and pyrophoric gas hazards, as well as hazards not otherwise

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classified, of the chemicals in the work area. OSHA Hazard Communication Standard (29 CFR 1910.1200).

International Organization for Standardization (ISO): ISO develops international standards on occupational health and safety management systems, risk assessment methodologies, and control measures. Relevant ISO standards include ISO 45001 (Occupational health and safety management systems) and ISO 31000 (Risk management).

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Coordinating agency or organisation

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0500 / CHEMICAL / Persistent Organic Pollutants (POPs)

Persistent Organic Pollutants

Definition

Persistent organic pollutants (POPs) are chemicals of global concern due to their potential for long-range transport, persistence in the environment, ability to bio-magnify and bio-accumulate in ecosystems, as well as their significant negative effects on human health and the environment.

References

WHO, 2020. Food safety: Persistent organic pollutants (POPs) World Health Organization (WHO). Food safety: Persistent organic pollutants (POPs) (who.int) Accessed 12 June 2024

Annotations

GHS Classification (UNECE, 2023)

Synonyms

Impurity, Contaminant, Pollutant

Additional scientific description

The most commonly encountered POPs are organochlorine pesticides, such as DDT, industrial chemicals, polychlorinated biphenyls (PCB) as well as unintentional by-products of many industrial processes, especially polychlorinated dibenzo-p-dioxins (PCDD) and dibenzofurans (PCDF), commonly known as dioxins.

Humans are exposed to these chemicals in a variety of ways: mainly through the food we eat (HIP CH0601), but also through the air we breathe, and through water, in the outdoors, indoors and at the workplace. Many products used in our daily lives may contain POPs, which have been added to improve product characteristics, such as flame retardants or surfactants. As a result, POPs can be found virtually everywhere on our planet in measurable concentrations.

POPs bio-magnify throughout the food chain and bio-accumulate in organisms. High concentrations of POPs are thus found in organisms at the top of the food chain. Consequently, trace levels of POPs can be found in the human body.

Human exposure - for some compounds and scenarios, even to low levels of POPs - can lead to many health effects, including increased cancer risk, reproductive disorders, alteration of the immune system, neurobehavioural impairment, endocrine disruption, genotoxicity and increased birth defects.

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Dioxins (HIP CH0502) are one of the most common classes of POPs. Dioxins and dioxin-like substances are three or two-ring structures chlorinated to varying degrees. Dioxin is also used as the colloquial (short) name of the toxic by-product (and sometimes contaminant) of herbicides: 2,3,7,8-tetrachlorodibenzo[*b,e*][1,4]-dioxin (IUPAC 2014). Polychlorinated biphenyls (PCBs) can have up to 10 chlorine atoms substituting for hydrogen atoms, and polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) can have up to eight. The compounds tend to have similar toxicity profiles and common mechanisms of action and are generally considered together as a group to set guidelines (WHO, 2019).

PCDDs and PCDFs are widely present in the environment, occurring naturally, but mainly as unwanted by-products of combustion and of various industrial processes.2,3,7,8-tetrachlorodibenzo[*b,e*][1,4]-dioxin (TCDD) was a contaminant of a herbicide (2,4,5-T) and chlorodibenzofurans (CDFs) were major contaminants of PCBs, but neither PCDDs nor PCDFs have ever been manufactured or used for commercial purposes other than for scientific research. PCBs were globally manufactured and used in the past (WHO, 2019).

Although PCB manufacture is now prohibited under the Stockholm Convention, release into the environment still occurs from environmentally circulating POPs, the disposal of large-scale electrical equipment and waste from metallurgical uses, and from some chemical manufacture and processing (WHO, 2019).

Human exposure to dioxins and dioxin-like substances has been associated with a range of toxic effects, including chloracne; reproductive, developmental and neurodevelopmental effects; immunotoxicity; and effects on thyroid hormones, liver and tooth development. Dioxins are also carcinogenic. Developmental effects are the most sensitive human health endpoint, making children, particularly breastfed infants, a population at elevated risk (WHO, 2019).

Another common example of POPs organochlorine pesticides such as DDT (HIPs CH0501, CH0502). Half a million tonnes of obsolete pesticides are scattered throughout the developing world. These toxic chemicals, often stored outdoors in leaking containers, are seeping into the soil and water. Eliminating these dangerous stocks is a development priority. Rural communities cannot hope to develop if the soil and water are contaminated with pesticides. People cannot hope to prosper if they are suffering from severe illnesses caused by pesticide poisoning. The Food and Agriculture Organization of the United Nations (FAO) Programme on the Prevention and Disposal of Obsolete Pesticides is working to inform the world about the dangers of obsolete pesticide stocks. It collaborates with developing countries to prevent more obsolete pesticides from accumulating and assists them in disposing of their existing stockpiles (FAO, 1999).

POPs are found in many obsolete pesticides, including insecticides, fungicides, herbicides, larvicides, acaricides, rodenticides, molluscides, nematocides, and aphicides. Around a thousand active ingredients are used to manufacture the wide array of pesticides in countries all over the world. Pesticide ingredients come in many thousands of different formulations. All these formulations degrade over time, although some are more persistent in the environment than others. The chemical by-products that form as the pesticide deteriorates can be more toxic than the original product.

Once pesticides enter soil, their fate depends on the physicochemical characteristics of the soil, such as moisture, texture, and soil organic matter content, as well as the pesticide properties. A relatively small amount of spilled pesticides can therefore create a much larger volume of polluted soil. For example, approximately 30 tonnes of pesticides were buried at a site in Yemen in the 1980s, contaminating over 1500 tonnes of soil. This can pose a serious health and environmental threat to nearby communities (FAO, 2000)

Metrics and numeric limits

Toxic equivalency factors (TEFs) have been derived to relate the toxicities of individual PCDDs, PCDFs and PCBs to the most toxic of these compounds: TCDD, which is used as a reference and given a TEF of 1. The common mechanism of action for these substances means that their effects are additive, and TEFs for individual compounds can be used to establish the summed toxicity of a mixture. This approach has proved robust as a method for establishing the relative toxicities of these compounds (WHO, 2019), and has resulted in the development of guideline values as follows:

Provisional tolerable monthly intake: In 2002, the Joint Food and Agriculture Organization of the United Nations (FAO)/WHO Expert Committee on Food Additives (JECFA) established a provisional tolerable intake of 70 pg/kg body weight per month for PCDDs, PCDFs and coplanar PCBs expressed as TEFs.

Air: An air quality guideline for PCBs was not established because direct inhalation exposures constitute only a small proportion of the total exposure – in the order of 1-2% of the daily intake from food (WHO, 2019).

The TEFs were updated in 2022 (WHO, 2023; DeVito, 2024).

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Key relevant UN convention / multilateral treaty

The Stockholm Convention on Persistent Organic Pollutants was adopted by the Conference of Plenipotentiaries on 22 May 2001 in Stockholm, Sweden (UNEP, 2001). The Convention entered into force on 17 May 2004. By September 2019, 183 UN member states and the European Union had adopted the Stockholm Convention.

United Nations (2015) Sustainable Development Goals. Preventing soil pollution could reduce soil degradation, increase food security, contribute substantially to the adaptation and mitigation of climate change, and contribute to the avoidance of conflict and migration. Therefore, taking immediate actions to combat soil pollution contributes to the achievement of almost all Sustainable Development Goals (SDGs) (FAO, 2018).

The Food and Agriculture Organization of the United Nations (FAO) Programme on the Prevention and Disposal of Obsolete Pesticides is working to inform the world about the dangers of obsolete pesticide stocks. It collaborates with developing countries to prevent more obsolete pesticides from accumulating and assists them in disposing of their existing stockpiles (FAO, 2025)

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Agricultural Sector: The agricultural sector is a major source of POPs. Pesticides and herbicides used in farming contribute significantly to POPs contamination.

Manufacturing Industries: Secondary sources include manufacturing industries. Chemical production, especially older processes, can release POPs into the environment1.

Recycling and Thermal Processes: Recycling and thermal processes (such as waste incineration) can release POPs when handling materials containing these chemicals.

Improper Waste Disposal: Ill-planned waste disposal, including landfill sites, can lead to POPs contamination of soil and water.

Reservoirs: Reservoirs, such as large bodies of water, can accumulate POPs over time.

Impacts of POPs cause direct or indirect impacts on the environment due to interactions among biotic and abiotic elements. Their contamination disrupts ecological systems and threatens the environmental integrity and health of living organisms. The global production of these pesticides started to decline in the 1980s in response to increasing concerns about negative impacts on environmental and human health, mainly because POPs are resistant to degradation, bioaccumulate in food chains, and have adverse effects on ecosystems and human health.

The wide use of PCBs in electrical equipment. such as transformers. means that any events (weather, geological, technological) that damage electrical facilities may release such molecules. Industrial sites where PCDDs and PCDFs are produced (for example. as by-products) may be contaminated and need remediation. Accidents at chemical plants or during the transport of hazardous materials can result in the sudden release of POPs. Use of certain pesticides can introduce POPs into the environment, which can be further spread by natural and anthropogenic processes. Poorly managed landfills and improper disposal of electronic waste can lead to the leaching of POPs into soil and groundwater, leading to contamination of food and feed.

Multi-hazard Context: The figure below summarises common interactions between persistent organic pollutants and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify. or be otherwise related to each other. Specific examples of multi-hazard context can be found in the ‘Hazard drivers’ and ‘Impacts’ sections above.

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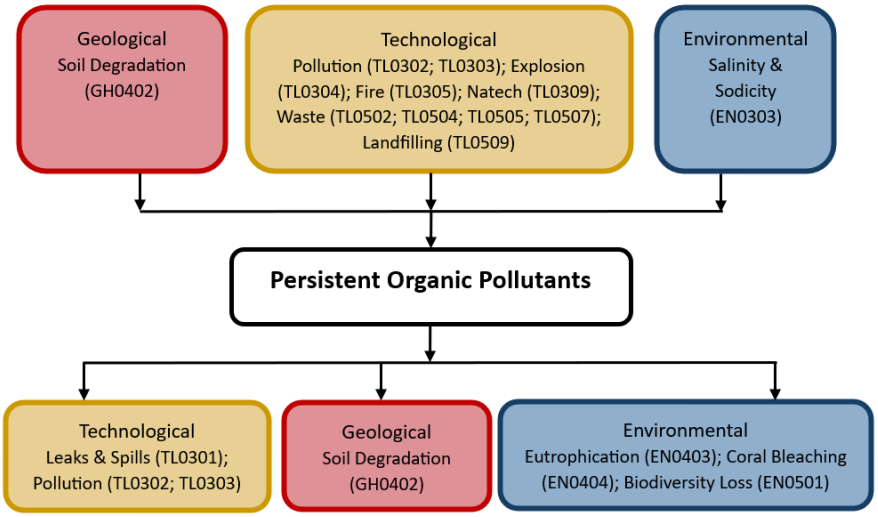

Monitoring: The section and the table below offer an overview of monitoring persistent organic pollutants. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	*Global Monitoring Plan (GMP) under the Stockholm Convention* Aims to provide a harmonized framework for monitoring the presence of POPs in the environment and human populations globally. *European Monitoring and Evaluation Programme (EMEP)* Focuses on monitoring air pollution, including POPs, across Europe to assess transboundary air pollution and support policymaking. *Integrated Atmospheric Deposition Network (IADN)* A U.S.-Canada initiative to monitor the deposition of toxic substances, including POPs, in the Great Lakes region.
How is the Hazard Observed/Monitored/Forecast?	The hazard posed by persistent organic pollutants (POPs) is monitored and forecasted through a combination of environmental sampling, predictive models, and real-time monitoring systems. Monitoring efforts are globally coordinated through organizations like UNEP, WHO, and national agencies, with data being shared internationally through frameworks such as the Stockholm Convention. These systems help assess current risks, forecast future trends, and issue early warnings in response to contamination events. The integration of meteorological, environmental, and health data plays a critical role in understanding and mitigating the long-term impact of POPs on both ecosystems and human health.

Risk Management: To address the risks associated with these substances, several steps have been taken to reduce or eliminate emissions of dioxins, dioxin-like PCBs and other related persistent organic pollutants. Many countries have now implemented the Stockholm Convention on POPs (2001), which suggests ending commercial use of 12 POPs and reduction or elimination of their emission into the environment. To monitor reduction in human exposure WHO and UNEP run a monitoring program for POPs in breastmilk. A steady decline in levels has been observed since 1980 for most countries.

In regard to food contamination, the FAO/WHO Codex Alimentarius Commission, which is a risk management body comprised of 169 member countries, is developing a draft code of practice for dioxins and dioxin-like PCBs in food, which identifies source-directed measures to reduce their presence in food, including fish, as well as a position paper, which provides an evaluation of the need for possible regulatory measures, such as limits in food and feed.

FAO and WHO consider fish to be an important component of a nutritious diet, and that the risk of consuming contaminated fish must be weighted in view of the beneficial nutritive effects of fish. FAO and WHO plan to develop general guidance for such risk-benefit considerations, with the contamination of fish as case studies. Dioxins and dioxin-like substances exposure occurs in the following ways (WHO, 2019):

- Associated with natural hazards: Dioxins can be generated by natural events, such as volcanic eruptions and forest fires.
- Industrial processes: PCDDs and PCDFs are by-products of industrial processes, particularly waste incineration, cement kilns firing hazardous waste, chlorine bleaching of pulp, and thermal processes in the

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metallurgical industry, as well as the manufacture of chlorophenols and phenoxy herbicides.

- Environmental media and food: Dioxin releases into air from inadequate incineration and releases into air, water or soil from industrial and waste sites contaminate soil and aquatic sediments, leading to bioaccumulation and bioconcentration through food chains. Most general population exposure is through ingestion of contaminated foods of animal origin.
- Waste disposal: Any source of organic materials in the presence of chlorine or other halogens will generate dioxins and furans during combustion. PCDDs and PCDFs are generated through the incineration of waste (domestic, industrial and health-care facilities) at low to moderate temperatures; guidance has been developed to identify and quantify releases from various incineration processes.

Actions to reduce emissions of these substances are required by the Stockholm Convention (UNEP, 2001). Interventions to reduce human exposure include: identifying and safely disposing of material containing or likely to generate dioxins and dioxin- like substances, such as electrical equipment; ensuring appropriate combustion practices to reduce emissions; implementing FAO/WHO strategies to reduce contamination in food and feed; and monitoring of food items, human breastmilk and air, as well as exposures in workers likely to be exposed to higher levels.

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Coordinating agency or organisation

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0501 / CHEMICAL / Persistent Organic Pollutants (POPs)

Pesticides

Definition

Pesticide means any substance, or mixture of substances of chemical or biological ingredients intended for repelling, destroying, or controlling any pest, or regulating plant growth.

Reference

UNEP, 2021. Highly Hazardous Pesticides (HHPs). www.unep.org/explore-topics/chemicals-waste/what-we-do/emerging-issues/highly-hazardous-pesticides-hhps Accessed 12 June 2024.

Preliminary – Corrections Pending

Annotations

GHS Classification (UNECE, 2023)

Synonyms

Defoliant, Fungicide. Insecticide, DDT, Paraquat, Weedkiller, Nanopesticide

Additional scientific description

Pesticides can also be grouped according to the types of pests which they kill: insecticides (insects); herbicides (plants); rodenticides (rodents); bactericides (bacteria); fungicides (fungi); and larvicides (larvae) (WHO and FAO, 2016). Pesticides are used in many different sectors (e.g., agriculture, forestry, food industry, domestic, etc.).

Insecticides are chemicals used to control insects by killing them (CDC, 2019). Insecticides are classified based on their structure and function. They include:

a) Carbamates/Organophosphates: Humans may be exposed via inhalation, ingestion, or through skin contamination; and acute and chronic exposure can produce varying levels of toxicity. Similar to the insects exposed, these pesticides disrupt the function of the human nervous system, mainly the brain. They have also been linked to cancer risk. Their toxicity to humans has led to bans and use restrictions in many countries (CDC, 2019).

b) Organochlorines: These are a group of chlorinated compounds that typically affect the central nervous system. They are known for their high toxicity, slow degradation, and bioaccumulation. Examples include dichlorodiphenyltrichloroethane (DDT), methoxychlor, chlordane, and lindane. Human exposure may occur via inhalation, ingestion, or through skin contamination. Many organochlorines have been banned in many countries, although a few are still registered for use (CDC, 2019).

c) Boric acid: This type of pesticide comes in many forms (most commonly in pellets/tablets or a finely ground powder) and has many uses. It is a combination of boron and other elements. Toxicity depends on the amount of boron in the product. In addition to controlling insects, boric acid can be used to control the growth of moulds, fungi and weeds. Boric acid is low in toxicity but can still cause irritation to the skin or eyes, and nausea, vomiting, stomach aches and diarrhoea if ingested (CDC, 2019).

d) Pyrethroids/Pyrethrins: Pyrethrum is a naturally occurring mixture of chemicals found in certain chrysanthemum flowers. Pyrethrum was first recognised as having insecticidal properties around 1800 in Asia and was used to kill ticks and various

insects such as fleas and mosquitos. From pyrethrum extract, individual chemicals called pyrethrins, which have active insecticidal properties were developed. Pyrethroids are manufactured chemicals that are very similar in structure to the pyrethrins, but are often more toxic to insects, as well as to mammals, and last longer in the environment than pyrethrins (ATSDR, 2003). These insecticides are used widely in households, agriculture, on pets, and in mosquito control. While they are generally less toxic to mammals than some other insecticides, they can still have harmful health effects (CDC, 2019).

Fungicides are pesticides that kill or slow the growth of fungi and their spores. They can be used to control fungi that damage plants, including rusts, mildews and blights. They might also be used to control mould and mildew in other settings. Fungicides work in a variety of ways, but most of them damage fungal cell membranes or interfere with energy production within fungal cells (NPIC, 2019).

Pesticides are inherently toxic, and among them, a small number of Highly Hazardous Pesticides cause disproportionate harm to the environment and human health. Highly Hazardous Pesticides means pesticides that are acknowledged to present particularly high levels of acute or chronic hazards to health or environment according to internationally accepted classification systems such as WHO or the Global Harmonized System (GHS) or their listing in relevant binding international agreements or conventions. In addition, pesticides that appear to cause severe or irreversible harm to health or the environment under conditions of use in a country may be considered to be and treated as highly hazardous.

Around a thousand active ingredients are used to manufacture the wide array of pesticides in countries all over the world. Pesticide ingredients come in many thousands of different formulations, including nanopesticide formulations in which an active ingredient is carried on or within a nanoparticle. All these formulations degrade over time although some are more persistent in the environment than others. The chemical by-products that form as the pesticide deteriorates can be more toxic than the original product (FAO, no date b).

Hazardous pesticide contamination in soils often results from improper storage of (obsolete) agrochemicals, as a result of which pesticides are spilled in the surroundings of the storage site, where they seep into the soil or are dispersed by wind. In some cases, pesticide spillage has been ongoing for many years. Such spillage may cause serious soil or groundwater contamination. In addition, highly toxic and persistent compounds have been used in agriculture for decades to control pests and diseases, which are proven to cause harm to non-target species. Although international agreements have been put in place to regulate the production and use of those highly toxic and persistent compounds, they will still remain in soils for several more decades. Moreover, in some countries, the international agreements are not yet being implemented or fully implemented, and therefore toxic pesticides are still being used. When soil and groundwater are contaminated, crops, livestock and drinking water may become affected and, when they are consumed by people, health risks may occur (FAO, 2000).

Once pesticides enter soil, their fate depends on the physicochemical characteristics of the soil, such as moisture, texture, and soil organic matter content, as well as the pesticide properties. A relatively small amount of spilled pesticides can therefore create a much larger volume of polluted soil. For example, approximately 30 tonnes of pesticides buried at a site in Yemen in the 1980s contaminated over 1500 tonnes of soil. This can pose a serious health and environmental threat to nearby communities (FAO, no date c).

Pesticide residue refers to the pesticides that may remain on or in food after they are applied to food crops or owing to their persistence in the environment or because of other uses, such as vector control to combat endemic pests such as mosquitos transmitting malaria. Risk of pesticide residues mainly concerns the occupational health of field workers, food safety (consumer health) and the environment. The maximum allowable levels of pesticide residues in foods are often stipulated by national regulatory bodies and by the Joint Food and Agriculture Organization of the United Nations (FAO) / World Health Organization (WHO) Food Standards Programme (Codex Alimentarius Commission).

The following definitions are relevant to the Codex Alimentarius (FAO, no date):

Pesticide: means any substance intended for preventing, destroying, attracting, repelling, or controlling any pest, including unwanted species of plants or animals during the production, storage, transport, distribution and processing of food, agricultural commodities, or animal feeds, or which may be administered to animals for the control of ectoparasites. The term can also include substances intended for use as a plant growth regulator, defoliant, desiccant, fruit-thinning agent, or sprouting inhibitor and substances applied to crops either before or after harvest to protect the commodity from deterioration during storage and transport. The term normally excludes fertilisers, plant and animal nutrients, food additives, and animal drugs.

Metrics and numeric limits

Available data are too limited to estimate the overall global health impacts of pesticides; however, the global impact of self-poisoning (suicides) from preventable pesticide ingestion was estimated to be 155,488 deaths and 7362,493 Disability Adjusted Life Years (DALYs) for 2016 (WHO, 2019).

The WHO provides maximum residue limits (MRLs) for pesticides in food and levels in drinking-water as follows (WHO, 2019):

Preliminary – Corrections Pending

- Maximum residue limits in food: The Joint Food and Agriculture Organization of the United Nations (FAO) / WHO Meeting on Pesticide Residues (JMPR) evaluates those pesticides likely to contaminate food. MRLs are published by the Codex Alimentarius Commission. Guidance for individual pesticides or pesticide components – including for a number of highly hazardous pesticides – can be accessed via the FAO, WHO, Codex Alimentarius Commission or National Framework for Chemicals Environmental Management (INCHEM) websites and in hard-copy publications.
- Drinking-water: WHO water quality guidelines exist for some pesticides used in agriculture and public health , including for some highly hazardous pesticides, where there is a likelihood of drinking-water contamination. Many pesticides have a maximum contaminant level given by the US Environmental Protection Agency of approximately 0.2 ppb (EPA, no date).

Key relevant UN convention / multilateral treaty

The Stockholm Convention on persistent organic pollutants (POPs) (UNEP, 2001). At the time of writing, there were 183 parties.

The Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Pesticides (1998). At the time of writing there were 161 parties.

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1989). At the time of writing, there were 187 parties.

The Montreal Protocol on Substances that Deplete the Ozone Layer (1987) has been ratified by all 197 UN Member States.

Examples of hazard drivers, impacts and risk management

Hazard Drivers of pesticide use include:

- Agricultural Productivity: The primary driver of pesticide use is the need to increase agricultural productivity. Pesticides help control pests and diseases that can significantly reduce crop yields.
- Economic Factors: The economic pressure to maximize crop yields and minimize losses drives farmers to use pesticides. The availability of cost-effective pesticides and their perceived benefits further incentivize their use.
- Technological Advancements: The development and commercialization of new pesticide formulations and delivery systems encourage their widespread use. Innovations in pest management techniques also play a role.
- Regulatory Policies: Government policies and subsidies can influence the use of pesticides. In some regions, subsidies for pesticide purchases promote their use, while regulations on permissible residues can limit it.
- Market Demands: Consumer preferences for aesthetically perfect produce lead farmers to use pesticides to ensure their crops meet market standards.

Impacts of exposure to highly hazardous pesticides include (WHO, 2019):

The use of pesticides in agriculture and other sectors intersects with multiple hazards, posing complex risks to health, environment, and economies. Pesticide exposure can cause immediate health effects such as skin rashes and respiratory issues, as well as long-term health effects including cancer, endocrine disruption and neurological disorders - vulnerable populations (such as children, pregnant women and agricultural workers) are particularly susceptible. The economic burden of health care for pesticide-related illnesses and the costs associated with environmental remediation can be substantial. Environmental hazards such as water contamination and soil degradation are caused by the leaching and accumulation of pesticides. Over-reliance on pesticides can lead to the development of resistant pest populations, necessitating the use of more or stronger chemicals, which increases costs for farmers. This could lead to a constant cycle of over-reliance leading to use of stronger pesticides leading to increased costs for health and environmental consequences. Pesticide residues on crops can affect market access, as international trade regulations and consumer preferences increasingly favour produce with low or no pesticide residues. (Aktar et al., 2009.; EEA, 2024; ILO, 2011). There is a possibility that excessive use of pesticides could reduce populations of insects required for plant pollination/reproduction, with consequent risks for food production.

Examples of impacts include:

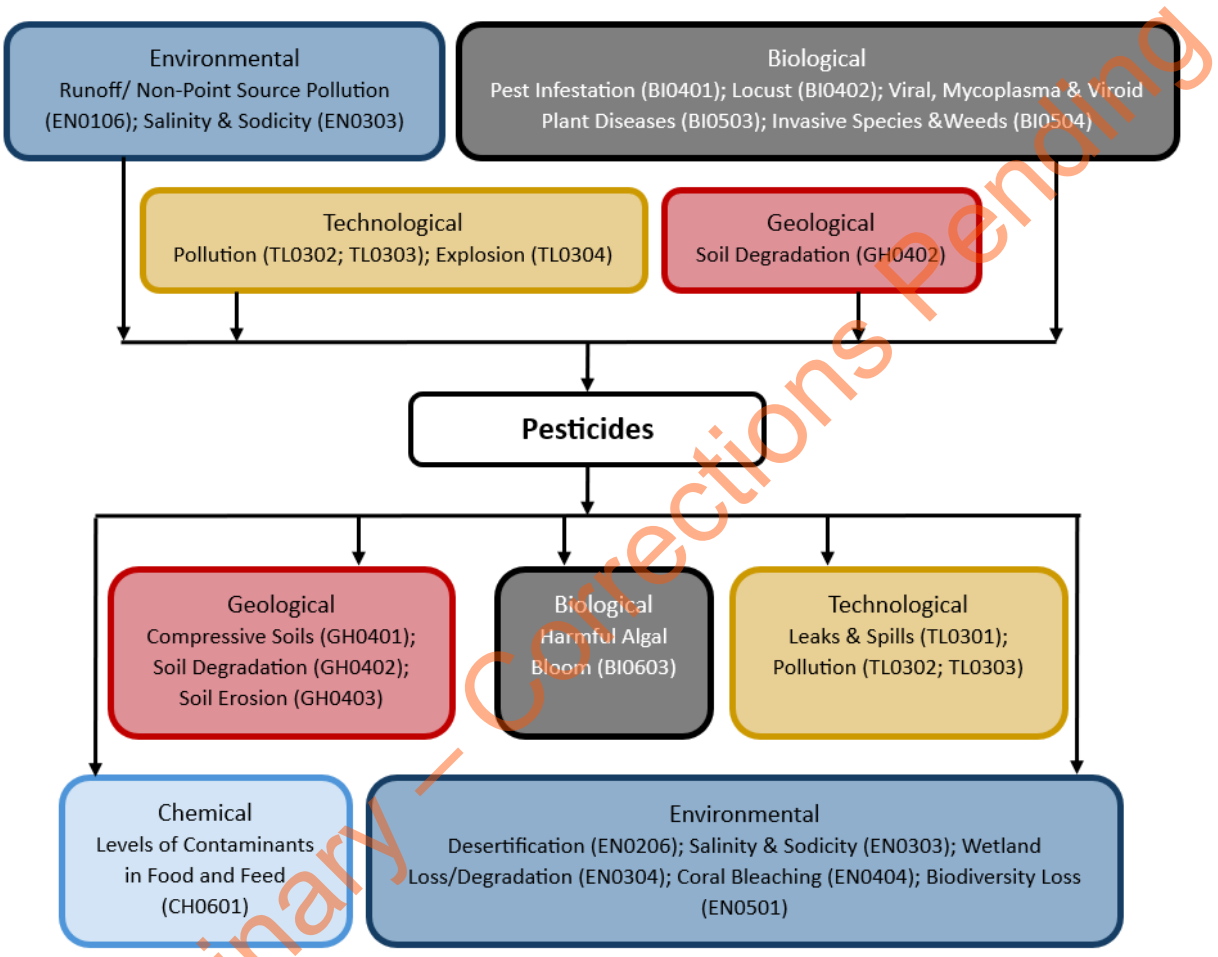
- Unintentional and self-inflicted (suicide) acute poisonings by pesticides are a serious public health concern in many parts of the world.
- The acute hazard is highly variable depending on the pesticide and includes peripheral and central neurotoxicity and reduced blood clotting capacity. The specific pesticide formulation can significantly affect both exposure and toxicity. Short-term exposure can cause harmful effects on the liver, kidneys, blood, lungs, nervous system, immune system and gastrointestinal tract.
- Chronic exposure to highly hazardous pesticides can affect the skin, eyes, nervous system, cardiovascular system,

Preliminary – Corrections Pending

gastrointestinal tract, liver, kidneys, reproductive system, endocrine system, immune system and blood. Some highly hazardous pesticides may cause cancer, including childhood cancer.

- Toddlers and children are considered more vulnerable to exposure to pesticides due to their smaller size, hand-to-mouth activity, different metabolism, and because they are still developing.

Multi-Hazard Context: The figure below summarises common interactions between pesticides and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



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Monitoring: The section and the table below offer an overview of monitoring pesticides. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information	1. World Health Organization (WHO) WHO is a key institution for providing information on pesticide hazards from a health perspecti The organization offers reports and data on the toxicological effects of pesticides and related chemicals, as well as the risks of exposure during disasters, including natural hazards like floods storms. 2. Food and Agriculture Organization (FAO) FAO works on disaster risk reduction related to chemicals, providing training, guidelines, and information to countries on preventing pesticide misuse in disaster contexts. 5. European Food Safety Authority (EFSA) In Europe, EFSA is responsible for assessing the risks posed by pesticides to human health and t environment. 6. Environmental Protection Agencies (National Level) National environmental or agricultural agencies, like the U.S. Environmental Protection Agency (EPA) or India's Central Insecticides Board, may also monitor and report pesticide-related hazar especially during environmental disasters (e.g., floods, wildfires, chemical spills). 7. International Programme on Chemical Safety (IPCS)

	The IPCS, a joint initiative between WHO, UNEP, and the International Labour Organization (ILO conducts assessments of chemical hazards, including pesticides, and provides guidelines and da to reduce risks, especially during emergencies.
How is the Hazard Observed/Monitored/Forecast	Pesticide hazards are monitored and forecasted using a multi-disciplinary approach that combines environmental monitoring, meteorological forecasting, remote sensing, risk assessment models, a emergency response systems. These efforts help reduce the potential for harmful pesticide exposu particularly in the context of natural disasters, and support effective risk management strategies t protect public health and the environment.

Risk Management: Risk mitigation measures are critical. In 2015, the Strategic Approach to International Chemicals Management (SAICM) International Conference on Chemicals Management adopted a resolution that recognised highly hazardous pesticides as an issue of concern and called for concerted action by countries to address these substances, with emphasis on promoting agro-ecologically based alternatives and strengthening national regulatory capacity to conduct risk assessment and risk management (WHO, 2019). Several initiatives undertaken by international organisations, including the WHO/FAO, support this resolution. These include the publication of guidelines to support the International Code of Conduct on Pesticide Management, including those on highly hazardous pesticides, Good Labelling Practice for Pesticides, Pesticide Legislation and other important resources and guidance documentation to assist in the implementation of best practices, which have been brought together in a toolkit (FAO, 2018).

The highly hazardous pesticides risk reduction process consists of three main consecutive steps: identification of highly hazardous pesticides by checking registered pesticides against the FAO/WHO criteria; assessment of highly hazardous pesticides by assessing each product for risks and needs to determine whether action is desirable; and mitigation of highly hazardous pesticides risks by determining for each product whether risk mitigation measures are required, and if so, which options would be most appropriate (WHO, 2019).

To reduce exposure to highly hazardous pesticides and their health impacts, the WHO summarised actions required in the following areas: handling, storage, use and disposal; elimination and replacement of pesticide use; education; and regulation, monitoring and surveillance (WHO, 2019).

Early Warning Systems for pesticides are multi-faceted and require a combination of technological, regulatory, and community-based approaches to be effective.

Pesticide Action Network (PAN):

- PAN works globally to monitor and reduce pesticide risks through community-based action and policy advocacy.

European Union's Pesticide Monitoring Program:

- The EU conducts comprehensive monitoring of pesticide residues in food and the environment, informing policy decisions.

Integrated Pest Management (IPM) Programs:

- Many countries implement IPM programs that focus on reducing pesticide use through alternative pest control methods and monitoring.

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Coordinating agency or organisation

Food and Agriculture Organization of the United Nations (FAO), World Health Organization (WHO).

International Union of Pure and Applied Chemistry (IUPAC).

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CH0502 / CHEMICAL / Persistent Organic Pollutants (POPs)

Dioxins and Dioxin-like Substances

Definition

Dioxins and dioxin-like substances, including polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are persistent organic pollutants (POPs, see CH0500) and are unwanted by-products of combustion and various industrial processes, such as the chlorine-bleaching of paper pulp and smelting. They can travel long distances from the source of emission, and bio-accumulate in food chains. These substances represent a major public health concern. They have been associated with a range of acute and long-term adverse health effects (WHO, 2019).

Reference

WHO, 2019. Preventing disease through healthy environments: Exposure to dioxins and dioxin-like substances: A major public health concern. World Health Organization (WHO). apps.who.int/iris/bitstream/handle/10665/329485/WHO-CED-PHE-EPE-19.4.4-eng.pdf?ua=1 Accessed 12 May 2024.

Annotations

GHS Classification (UNECE, 2023)

Synonyms

Main classes: polychlorinated biphenyls (PCBs); polychlorinated dibenzo-p-dioxins (PCDDs); polychlorinated dibenzofurans (PCDFs)

Additional scientific description

Dioxins and dioxin-like substances' are three- or two-ring structures chlorinated to varying degrees. Dioxin is also used as a common name of the toxic by-product (and sometimes contaminant) of herbicides: 2,3,7,8-tetrachlorodibenzo[*b,e*][1,4]-dioxin (IUPAC 2014). Polychlorinated biphenyls (PCBs) can have up to 10 chlorine atoms substituting for hydrogen atoms, and polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) can have up to eight. The compounds tend to have similar toxicity profiles and common mechanisms of action and are generally considered together as a group to set guidelines (WHO, 2019). The International Labour Organisation provides a safety card for 2,3,7,8-tetrachlorodibenzo[*b,e*][1,4]-dioxin (ILO, no date).

PCDDs and PCDFs are widely present in the environment, occurring naturally, but mainly as unwanted by-products of combustion and of various industrial processes. 2,3,7,8-tetrachlorodibenzo[*b,e*][1,4]-dioxin (TCDD) was a contaminant of a herbicide (2,4,5-T) and chlorodibenzofurans (CDFs) were major contaminants of PCBs, but neither PCDDs nor PCDFs have ever been manufactured or used for commercial purposes other than for scientific research. PCBs were globally manufactured and used in the past (WHO, 2019).

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Although PCB manufacture is now prohibited under the Stockholm Convention, release into the environment still occurs from the disposal of large-scale electrical equipment and waste, from metallurgical uses, and from some chemical manufacture and processing (WHO, 2019).

Human exposure to dioxins and dioxin-like substances has been associated with a range of toxic effects, including chloracne; reproductive, developmental and neurodevelopmental effects; immunotoxicity; and effects on thyroid hormones, liver and tooth development. Dioxins are also carcinogenic. Developmental effects are the most sensitive human health endpoint, making children, particularly breastfed infants, a population at elevated risk (WHO, 2019).

Metrics and numeric limits

Toxic equivalency factors (TEFs) have been derived to relate the toxicities of individual PCDDs, PCDFs and PCBs to the most toxic of these compounds: TCDD, which is used as a reference and given a TEF of 1. The common mechanism of action for these substances means that their effects are additive, and TEFs for individual compounds can be used to establish the summed toxicity of a mixture. This approach has proved robust as a method for establishing the relative toxicities of these compounds (WHO, 2019), and has resulted in the development of guideline values as follows:

Provisional tolerable monthly intake: In 2002, the Joint Food and Agriculture Organization of the United Nations (FAO)/WHO Expert Committee on Food Additives (JECFA) established a provisional tolerable intake of 70 pg/kg body weight/month for PCDDs, PCDFs and coplanar PCBs expressed as TEFs. The TEFs were updated in 2022 (WHO, 2023; DeVito, 2024).

Drinking water: maximum contaminant level is given by the US Environmental Protection Agency as 0.00003 ppb (EPA, no date)

Air: An air quality guideline for PCBs was not established because direct inhalation exposures constitute only a small proportion of the total exposure – in the order of 1–2% of the daily intake from food (WHO, 2019).

Key relevant UN convention / multilateral treaty

The Stockholm Convention on Persistent Organic Pollutants was adopted by the Conference of Plenipotentiaries on 22 May 2001 in Stockholm, Sweden (UNEP, 2001). The Convention entered into force on 17 May 2004. By September 2019, 183 UN member states and the European Union had adopted the Stockholm Convention.

Examples of hazard drivers, impacts and risk management

Hazard Drivers Dioxins and dioxin-like substances exposure occurs in the following ways (WHO, 2019):

- Associated with natural hazards: Dioxins can be generated by natural events, such as volcanic eruptions and forest fires.
- Industrial processes: PCDDs and PCDFs are by-products of industrial processes, particularly waste incineration, cement kilns firing hazardous waste, chlorine bleaching of pulp, and thermal processes in the metallurgical industry, as well as the manufacture of chlorophenols and phenoxy herbicides.
- Environmental media and food: Dioxin releases into air from inadequate incineration and releases into air, water or soil from industrial and waste sites contaminate soil and aquatic sediments, leading to bio-accumulation and bioconcentration through food chains. Most general population exposure is through ingestion of contaminated foods of animal origin.
- Waste disposal: Any source of organic materials in the presence of chlorine or other halogens will generate dioxins and furans during combustion. PCDDs and PCDFs are generated through the incineration of waste (domestic, industrial and health-care facilities) at low to moderate temperatures; guidance has been developed to identify and quantify releases from various incineration processes.
- The wide use of PCBs in electrical equipment, such as transformers, means that any events (weather, geological, technological) that damage electrical facilities may release such molecules. Industrial sites where PCDDs and PCDFs are produced (for example, as by-products) may be contaminated and need remediation. Climate change and its effects may lead to wider dispersal of persistent organic pollutants (Teran 2012).

Impacts: Dioxins are carcinogenic and produce negative reproductive and developmental effects.

Multi-hazard Context: The figure below summarises common interactions between dioxins & dioxin-like substances and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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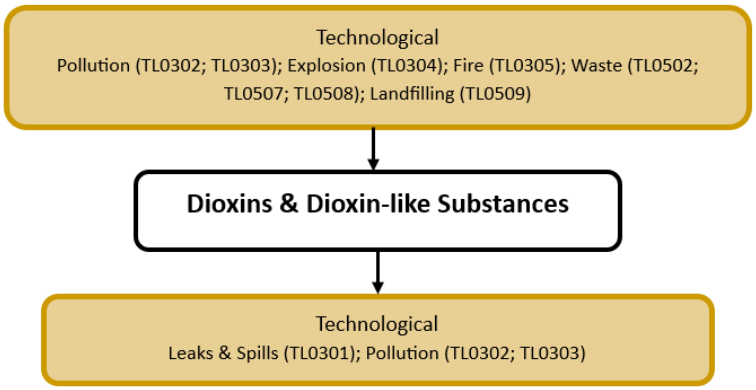

Monitoring: The section and the table below offer an overview of monitoring dioxins & dioxin-like substances. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster I Data/Information?	UNEP, 2001. Stockholm Convention on Persistent Organic Pollutants. WHO, 2023, WHO Fact Sheets Dioxins.
How is the Hazard Observed/Monitored/Forecast?	The Dioxin Monitoring Program - The EPA monitors dioxin levels in various media, including ai soil, and water, and conducts periodic National Dioxin Air Monitoring Network (NDAMN) assessments. (EPA, 2018) Japan's Dioxin Monitoring Network - Japan has established a comprehensive monitoring netw that includes regular sampling and analysis of dioxins in the environment and food supply, supported by rigorous regulatory standards. The Rapid Alert System for Food and Feed (RASFF) - as part of the food safety tools in Europe, RASFF was established to ensure the exchange of information between member countries to support swift reaction by food safety authorities in case of risks to public health resulting from food chain. (EC, 2024)

Risk Management: Actions to reduce emissions of these substances are required by the Stockholm Convention (UNEP, 2001). Interventions to reduce human exposure include: identifying and safely disposing of material containing or likely to generate dioxins and dioxin- like substances, such as electrical equipment; ensuring appropriate combustion practices to reduce emissions; implementing FAO/WHO strategies to reduce contamination in food and feed; and monitoring of food items, human breastmilk and air, as well as exposures in workers likely to be exposed to higher levels.

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Coordinating agency or organisation

Not identified.

Preliminary – Corrections Pending

CH0503 / CHEMICAL / Persistent Organic Pollutants (POPs)

Perfluoroalkyl and Polyfluoroalkyl Substances

Definition

Polyfluoroalkyl substances (PFAS) are a large family of chemicals in which multiple fluorine atoms are attached to an alkyl chain within a molecule. If all possible sites of an alkyl chain are occupied by fluorine atoms, the substance may also be referred to as a perfluoroalkyl substance as in perfluorooctanoic acid (PFOA) or perfluorooctanesulfonic acid (PFOS). (WHO, 2023).

Reference

WHO, 2023. PFOS and PFOA in Drinking-water: Background document for development of WHO Guidelines for Drinking-water Quality (WHO). https://www.who.int/teams/environment-climate-change-and-health/water-sanitation-and-health/chemical-hazards-in-drinking-water/per-and-polyfluoroalkyl-substances. Accessed 16 November 2024

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Annotations

GHS Classification (UNECE, 2023)

Synonyms

"Forever Chemicals", fluorinated compounds, Perfluorinated Compounds, Fluoropolymers, PFCs (Perfluorinated Chemicals), Fluoroalkyl Substances, Teflon Chemicals

Additional scientific description

PFAS are a large family of chemicals with a common feature: they contain carbon-fluorine bonds that make them highly stable, persistent, and resistant to degradation. They are widely used in various consumer products and industrial applications, but they also raise significant environmental and health concerns due to their persistence in the environment and their potential to accumulate in the human body. The European Union, The EU Commission, the U.S. Environmental Protection Agency (EPA), Centers for Disease Control and Prevention (CDC), and other health agencies have ongoing research and guidelines regarding the regulation, monitoring, and health risks associated with PFAS exposure. Because of their chemical structure, PFAS are also referred to as “forever chemicals” because they do not break down easily over time.

The most widely studied of these PFAS are perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA). Although the stability of PFOS and PFOA as well as their surfactant properties make them useful in consumer and industrial applications, there are concerns with their persistence and impacts on the environment and human health, as a result of exposure through the widespread uses of these chemicals. Drinking-water is one of several environmental sources of human exposure to PFAS, along with exposure via food, use in consumer products and occupational exposures (WHO, 2023)

Key Characteristics:

- Persistence: PFAS are extremely persistent in the environment and in human bodies due to the strong carbon-fluorine bond.
- Wide Application: PFAS are used in products such as stain-resistant fabrics, waterproofing agents, firefighting foams, and non-stick cookware.
- Health Concerns: Many PFAS chemicals have been linked to adverse health effects, including developmental effects, immune system disruption, liver toxicity, and cancer.

Metrics and numeric limits

PFAS (Per- and Polyfluoroalkyl Substances) are a large class of human-made chemicals, and various organizations, including the European Union, the EU Commission, the U.S. Environmental Protection Agency (EPA), World Health Organization (WHO), and other health and environmental regulatory bodies, have set guidelines and limits to manage exposure. These limits pertain to drinking-water quality, environmental contamination, food safety, waste management, and occupational exposure. Below are key metrics, numeric limits, and relevant guidelines.

On April 10, 2024, EPA announced the final National Drinking Water Standards for six PFAS (PFOS, PFOA, PFNA, PFBS, PFHxS, and GenX). The new limits require public water systems to monitor for PFAS at some of the lowest levels ever regulated. It also requires water systems to notify the public of PFAS levels in their drinking -water and take action if above the regulated values (US EPA, 2025).

In October 2022, the European Environment Agency (EEA) proposed quality standards for the sum of 24 PFAS, including PFOS, in surface water and groundwater. These were based on an opinion of the European Food Safety Authority (EFSA), supported by opinions of the Scientific Committee on Health, Environment and Emerging Risks. The proposed standard for surface and groundwaters is 4.4 ng/L (as PFOA equivalents) (EU, no date).

The key EU regulation for PFAS in drinking-water is the recast Drinking Water Directive (EU) 2020/2184, which came into force in January 2021 (EU, 2020).

WHO is still reviewing the available scientific evidence and has not yet established definitive guideline values for PFAS in drinking-water. The organization is continuing to assess the potential health risks associated with PFAS exposure through drinking-water and other sources.

Summary of Key Numeric Limits for PFAS in drinking-water:

Standard/Agency	PFAS Compound	Limit	Effective date
US EPA 2025	PFOA, PFOS	4.0 ppt (individually)	2029
US EPA 2025	PFHxS, PFNA, HFPO-DA (GenX)	10 ppt (individually)	2029
EU, no date	Sum of 20 PFAS	100 ng/L	2026
EU, no date	Total PFAS	500 ng/L	2026

Key relevant UN convention/multilateral treaty

PFAS are included in the Stockholm Convention. The Stockholm Convention on Persistent Organic Pollutants was adopted by the Conference of Plenipotentiaries on 22 May 2001 in Stockholm, Sweden (UNEP, 2001). The Convention entered into force on 17 May 2004. By September 2019, 183 UN member states and the European Union had adopted the Stockholm Convention.

Examples of hazard drivers, impacts and risk management

Hazard Drivers:

1. Widespread Industrial Use: PFAS chemicals have been used in a wide range of industries due to their water- and oil-repellent properties, chemical stability, and resistance to heat. This widespread use has led to their persistent presence in the environment.
2. Regulatory Gaps and Historical Use: PFAS were largely used before their full health and environmental risks were understood. In the past, chemicals like PFOA and PFOS were not well-regulated, and manufacturers did not initially recognize their long-term persistence;.
3. Environmental Persistence: PFAS are resistant to environmental degradation, leading to bioaccumulation in ecosystems. Once released into the environment, they can persist for decades or longer.

Impacts: PFAS are, in general, not an acute toxic substance to human health in the concentrations that normally surround humans. But given its effect on a long-term basis or in high doses due to e.g. accidents at chemical industry plants or industrial

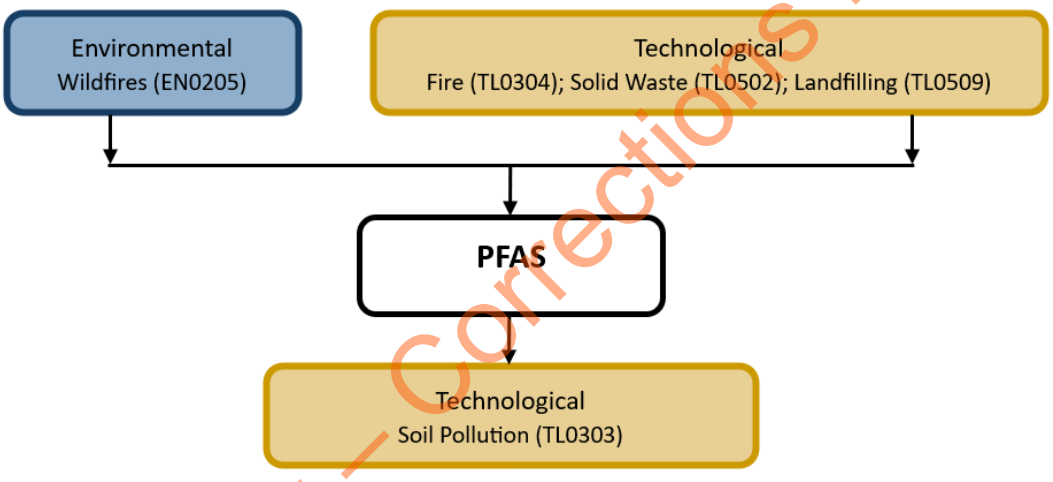
Preliminary – Corrections Pending

sites using PFAS in their production - such exposure could pose an increased risk to human health in a disaster situation. PFAS is so widespread - and is/has been used in many products - and it is found all over the world - including many inland water streams and rivers etc. - and in the sea - so when flooding occurs - due to heavy storms, increasing due to climatic change - PFAS contamination will follow. Therefore, monitoring is vital.

1. Health Impacts: PFAS are linked to a range of adverse health outcomes, including developmental, immune, liver, and kidney problems, and may be carcinogenic (EEA, 2023; IARC, 2025; CDC, no date).
2. Environmental Impacts: PFAS compounds can contaminate soil, water, and wildlife, leading to widespread environmental contamination that is difficult to remediate (EEA 2024).
3. Economic Impacts: The economic cost of PFAS contamination includes the cost of water treatment, cleanup of contaminated sites, and potential litigation.

Multi-hazard Context: The figure below summarises common interactions between PFAS and other hazards. Particular note should be made of fire as a multi-hazard context. Many fire-fighting foams contain PFAS, which raises the concern that response to one disaster situation could precipitate another (related to PFAS, in this case).

This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring PFAS. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster F Data/Information?	World Health Organisation (WHO) Environmental protection agencies
How is the Hazard Observed/Monitored/Forecast?	Environmental monitoring, advanced detection technologies, public h advisories, and regulatory frameworks

Risk Management:

1. Regulatory Actions: Governments around the world are increasing efforts to regulate PFAS and reduce exposure to these chemicals. The EU has set drinking water standards for PFAS, specifically PFOS + PFOA, limiting their presence to 0.1 µg/L (100 ng/L). The European Food Safety Authority has a significant programme of work related to PFAS (EFSA, 2024) Stockholm Convention. PFOS has been listed under the Stockholm Convention on Persistent Organic Pollutants (POPs), which regulates the production and use of certain persistent chemicals.
2. Technological Solutions for Remediation: Various technologies are being explored or used to address PFAS contamination, especially in drinking water and soil (EPA, no date).
3. Public Health and Awareness Campaigns: Increasing public awareness of PFAS risks is a key strategy in risk management (e.g. EWG, no date).

Early warning systems for PFAS contamination are critical for protecting public health and the environment. They rely on environmental monitoring, advanced detection technologies, public health advisories, and regulatory frameworks to identify contamination before it reaches dangerous levels. These systems also require collaboration across sectors and regions to

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address global contamination issues effectively. Key players such as the EPA, WHO, OECD, and regional governments are taking significant steps to build and enhance early warning systems to prevent and mitigate PFAS-related risks. Key Components of Early Warning Systems for PFAS are: 1. Environmental Monitoring; 2. Regulatory Surveillance and Health Impact Studies; Public Data Platforms and Transparency; 4. Early Detection Technologies; 5. International Collaboration

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Coordinating agency or organisation

World Health Organization (WHO); International Union of Pure and Applied Chemistry (IUPAC).

Preliminary – Corrections Pending

CH0504 / CHEMICAL / Persistent Organic Pollutants (POPs)

Microplastics

Definition

Microplastics are small plastic pieces less than five millimetres in length, which can be harmful to the environment, especially marine life. They originate from a variety of sources, including larger plastic debris that degrades into progressively smaller pieces (adapted from UNEP, 2016 and NOAA, 2023).

References

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Preliminary – Corrections Pending

Annotations

GHS Classification (UNECE, 2023)

Synonyms

Microparticles (IUPAC, 2012), Marine debris, microbeads, plastic particles.

Additional scientific description

Microplastics are routinely defined as small particles or fragments of plastic measuring less than 5 mm in length, which are insoluble in the aqueous environment. The broad classification of these small plastic residues is based on their size; (i) large microplastics of size ranging between 5 mm to 1 mm, (ii) small microplastics of 1 mm to 1 µm size range, and (iii) nanoplastics of <1 µm size. A more scientifically rigorous definition of plastic pieces might refer to nano, micro, meso, macro and mega-size ranges, although this has not yet been formally proposed for adoption by the international research community. At present, the lack of an agreed nomenclature, together with practical difficulties of sampling and measuring different size ranges in the field, has encouraged the widespread adoption of microplastics as a generic term for 'small' pieces of plastic.

There are primary and secondary sources of microplastics. The distinction is based on whether the particles were originally manufactured to be that size (primary) or whether they have resulted from the breakdown of larger items (secondary). Some microplastics are intentionally manufactured for industrial and domestic purposes ('primary'

microplastics). These include 'microbeads' used in cosmetic and personal healthcare products, such as toothpaste. 'Secondary' microplastics are created by the weathering and fragmentation of larger plastic objects. Weathering and fragmentation are enhanced by exposure to ultraviolet (UV) irradiation. These processes become extremely slow in the absence of UV radiation, as is the case in much of the ocean. Plastics marked as 'biodegradable' degrade more slowly in the ocean (UNEP, 2016). There is evidence that microplastics are littered into the environment at all steps in the life cycle of a plastic product, from producers to waste management. Microplastics can enter the marine environment via riverine systems, coastlines, directly at sea from vessels and platforms, or by wind-induced transport in the atmosphere. Methods of defining microplastics, sampling and measurement vary considerably among studies, source sectors and geographical regions, making it difficult to synthesize data across studies.

A special subclass of microplastics is nanoplastics. Nanoplastics are a form of marine debris, the significance of which is only now emerging. They are minuscule particles with dimensions of 1 to 100 nanometres (a nanometre is one millionth of a millimetre). It is important to note that nanoplastics do not have any legal definition, but the general definitions of nanomaterials can be adapted to nanoplastic particles. The most important definitions can be found in the standards ISO/TS 80004-1:2015, the regulation (EC) no 1223/2009 on cosmetic products, the regulation (EU) 2015/2283 on novel foods, and the regulation (EU) 1169/2011 on the provision of food information to consumers. Applying these definitions for polymer-based particles, it can be used as a definition for nanoplastics. It is very common for the two terms, nanoplastics and nanoparticles, to be used interchangeably in the literature.

A large proportion of the nanoplastic particles found in the ocean are of natural origin. It is the anthropogenic nanoplastics that are of concern. These originate from two sources: (i) nanoparticles created intentionally for use in industrial processes and cosmetics and (ii) from the breakdown of plastics in marine debris, from fragments of artificial fabrics discharged into urban wastewater, and through leaching from land-based waste sites (NOAA, 2021).

Recent scientific research has highlighted the potential environmental impacts of nanoplastics. For example, they appear to reduce primary production and the uptake of food by zooplankton and filter-feeders. Nanoparticles of titanium dioxide, which is widely used in paints and metal coatings and in cosmetics, are of particular concern. When nanoparticles of titanium dioxide are exposed to UV radiation from the sun, they transform into a disinfectant and have been shown to kill phytoplankton, which are the basis of primary production in the ocean. The scale of the threat from nanoparticles is unknown, and further research is required (UN, 2017).

About half the global population lives within 100 km of a coastline, and population growth is greatest in that zone. This means the amount of plastic debris entering the ocean from land-based sources is likely to increase unless significant changes are made to waste management practices on land (UNEP, no date).

Biodegradable plastics - Biodegradable polymers are able to undergo degradation into small molecules such as carbon dioxide (CO_2), methane (CH_4), and H_2O due to the action of biota, usually microorganisms, at a rate that is much faster than that for common plastics. The bio-prefix in bio-PE, bio-PET or bio-PA does not suggest that these polymers will therefore also be biodegradable. Some biopolymers, bio-derived plastics and bio-based plastics are indeed biodegradable. However, others in the same categories, such as the bio-based plastic bio-PE or the bio-derived plastic, fully acetylated cellulose, are not biodegradable.

Metrics and numeric limits

1. Environmental Metrics and Limits

Water Bodies: European Union (EU): The EU has proposed a threshold of 20 microplastic particles per litre of water for freshwater environments. This guideline is part of the broader Water Framework Directive aimed at maintaining the good ecological status of water bodies (European Commission, 2018)

United States Environmental Protection Agency (EPA): The EPA has yet to establish regulatory limits for microplastics in water, but they are actively researching the prevalence and impacts of microplastics (EPA, 2020).

Soil and Sediments: Research Studies: Studies have found varying concentrations of microplastics in soils and sediments. For instance, a study in agricultural soils found concentrations ranging from 78 to 593 microplastic particles per kilogram of dry soil (Piehl et al., 2018).

2. Human Health Metrics and Limits:

Drinking Water - The WHO has reviewed the presence of microplastics in drinking water and concluded that current evidence does not suggest significant health risks at present levels. However, they emphasize the need for further research (WHO, 2019).

Food Products - European Food Safety Authority has conducted risk assessments on microplastics in seafood, estimating that a European consumer might ingest up to 11,000 microplastic particles annually through seafood consumption (EFSA, 2016).

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3. Air Quality: Research Findings: Studies have found microplastics in indoor and outdoor air with varying concentrations. Indoor environments have been reported to have higher concentrations, ranging from 1 to 60 microplastic fibres per cubic meter (Dris et al., 2016).

4. Regulatory and Research Initiatives: United Nations Environment Programme (UNEP): UNEP is working on global guidelines and frameworks to address plastic pollution, including microplastics, with an emphasis on prevention and reduction strategies (UNEP, 2018).

Microplastic Research Projects: Various international projects are underway to understand the sources, distribution, and effects of microplastics. Notable examples include the "Microplastic Pollution" project by the National Oceanic and Atmospheric Administration (NOAA) and the European Marine Strategy Framework Directive.

Key relevant UN convention / multilateral treaty

The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972, the 'London Convention' for short, is one of the first global conventions to protect the marine environment from human activities and has been in force since 1975 (IMO, 1972). Its objective is to promote the effective control of all sources of marine pollution and to take all practicable steps to prevent pollution of the sea by dumping of wastes and other matter. Currently, 87 States are Parties to this Convention.

The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main international convention covering the prevention of pollution of the marine environment by ships from operational or accidental causes (IMO, 1996). The MARPOL Convention was adopted on 2 November 1973. The Protocol of 1978 was adopted in response to a spate of tanker accidents in 1976-1977. As the 1973 MARPOL Convention had not yet entered into force, the 1978 MARPOL Protocol absorbed the parent Convention. The combined instrument entered into force on 2 October 1983. In 1997, a Protocol was adopted to amend the Convention, and a new Annex VI was added, which entered into force on 19 May 2005. MARPOL has been updated by amendments over the years.

UN Member States endorsed a historic resolution to End Plastic Pollution and forge an international legally binding agreement by 2024. The resolution addresses the full lifecycle of plastic, including its production, design and disposal. The resolution, based on three initial draft resolutions from various nations, establishes an Intergovernmental Negotiating Committee (INC), which will begin its work in 2022, with the ambition of completing a draft global legally binding agreement by the end of 2024. It is expected to present a legally binding instrument, which would reflect diverse alternatives to address the full lifecycle of plastics, the design of reusable and recyclable products and materials, and the need for enhanced international collaboration to facilitate access to technology, capacity building and scientific and technical cooperation.

The BRS (Basel, Rotterdam, and Stockholm) Conventions are not specifically dedicated to plastic pollution, but they play a significant role in addressing various aspects of plastic waste management and chemical pollution. The Basel Convention is the most relevant of the three conventions for addressing plastic pollution: a) Plastic Waste Amendments: In 2019, the Conference of the Parties adopted amendments to include plastic waste in the scope of the Convention; b) Partnership on Plastic Waste (PWP): Established to improve and promote environmentally sound management of plastic waste and minimize its generation; c) Technical Guidelines: The Convention is updating guidelines for the identification and environmentally sound management of plastic wastes. The BRS Conventions are working together to address plastic pollution holistically, including its chemical components.

Examples of hazard drivers, impacts and risk management

Hazard Drivers *Primary Sources* - i) Personal Care Products: Microbeads in exfoliating scrubs, toothpaste, and cosmetics; ii) Industrial Applications: Microplastics used in sandblasting and as raw materials in manufacturing processes; iii) Agricultural Practices: Plastic mulching films and controlled-release fertilizers.

Secondary Sources - i) Plastic Waste Degradation: Larger plastic items breaking down into smaller particles through weathering, UV radiation, and mechanical action; ii) Synthetic Textiles: Microfibers released during the washing of synthetic fabrics like polyester and nylon; iii) Tire Wear: Tiny particles generated from the abrasion of tires on roads.

Environmental Dispersal Mechanisms - i) Atmospheric Transport: Microplastics can be carried by wind and atmospheric currents, depositing in remote areas; ii) Waterways: Rivers and streams transport microplastics from urban and rural areas to oceans; iii) Wastewater Treatment Plants: Effluent and sludge from treatment plants can contain and spread microplastics.

Given that humans can be exposed to microplastics through a variety of environmental media, including food and air, a better understanding of overall exposure to microplastics from the broader environment is needed (WHO, 2020).

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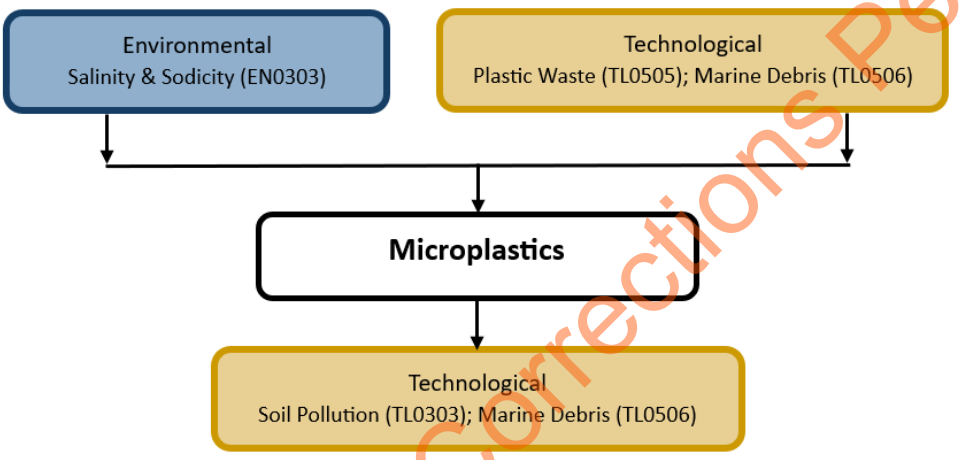
Impacts *Environmental Impacts - i) Marine* Ecosystems: Ingestion by marine organisms, leading to physical harm, digestive blockages, and chemical exposure; ii) Soil Health: Accumulation in agricultural soils, affecting soil structure and potentially entering the food chain through crops; iii) Freshwater Systems: Contamination of lakes and rivers, impacting freshwater species and ecosystems. *Human Health Impacts* - i) Ingestion: Consumption of microplastics through contaminated food and water, potentially leading to exposure to toxic chemicals; ii) Inhalation: Breathing in microplastic particles present in the air, particularly in urban environments; iii) Chemical Exposure: Microplastics can adsorb harmful pollutants, which can then enter the human body, posing risks such as endocrine disruption and carcinogenic effects. *Economic Impacts* - i) Fishing Industry: Decreased fish populations and contamination of seafood, affecting livelihoods and economies dependent on fishing; ii) Tourism: Pollution of beaches and water bodies can deter tourists, impacting local economies; iii) Waste Management Costs: Increased costs for cleaning up plastic pollution and managing waste effectively.

Multi-Hazard Context: The figure below summarises common interactions between microplastics and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Addressing the issue of microplastics in a multi-hazard context requires an integrated approach that considers the interactions between various environmental, anthropogenic, and socioeconomic factors. Effective management strategies must encompass regulatory measures, technological innovations, public engagement, and international cooperation to mitigate the impacts of microplastics on both the environment and human health. as demonstrated in the two cases below:

North Pacific Gyre (Great Pacific Garbage Patch)

Drivers: Ocean currents and human activity.

Impacts: Significant accumulation of microplastics affecting marine life and potentially entering the human food chain.

Risk Management: Initiatives like The Ocean Cleanup project aim to remove plastics from the ocean.

Urban Stormwater Management in Los Angeles

Drivers: Urban runoff and ineffective waste management.

Impacts: Microplastics are transported to the ocean, impacting marine ecosystems.

Risk Management: Implementation of green infrastructure and improved stormwater management practices to reduce runoff pollution.

Monitoring: The section and the table below offer an overview of monitoring microplastics. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	UNEP Global Monitoring Plan (GMP) – through its Global Monitoring Plan (GMP), collaborates with countries and organisations to monitor persistent pollutants, including microplastics, in air, water, and soil European Commission – Marine Strategy Framework Directive - OJ L 164, 25.6.2008, p. 19–40

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	The Ocean Cleanup – Plastic Pollution Index - PPI is a tool developed to map and predict plastic pollution, including microplastics, in marine environments The International Maritime Organization's (IMO) MARPOL Annex V
How is the Hazard Observed/Monitored/Forecast?	As made clear under Drivers, above, asbestos release is often a result of other events that cause damage or fires in the vicinity of asbestos fibres (see Multi-Hazard Context). Early warning will therefore be related to those precipitating events coupled with good risk management related to mapping areas with high asbestos burdens.

Risk Management The human health risk from microplastics in drinking water is a function of both hazard and exposure. Potential hazards associated with microplastics come in three forms: the particles themselves which present a physical hazard, chemicals (unbound monomers, additives, and sorbed chemicals from the environment), and microorganisms that may attach to and colonise microplastics, known as biofilms. Based on the limited evidence available, chemicals and microbial pathogens associated with microplastics in drinking water pose a low concern for human health. Although there is insufficient information to draw firm conclusions on the toxicity of nanoparticles, no reliable information suggests it is a concern (WHO, 2020).

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Coordinating agency or organization

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0601 / CHEMICAL / Chemical Hazards in Food and Pharmaceuticals

Levels of Contaminants in Food and Feed

Definition

A contaminant in food and feed is defined as any substance not intentionally added but present in such food or feed as a result of the production, manufacture, processing, preparation, treatment, packing, packaging, transport or storage, or as a result of environmental contamination, which can lead to major public hazards (FAO and WHO, 2019).

Reference

FAO and WHO, 2019. Codex Alimentarius Commission – Procedural Manual twenty-seventh edition. Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO). www.fao.org/3/ca2329en/CA2329EN.pdf Accessed 1 July 2024

Preliminary – Corrections Pending

Annotations

GHS Classification (UNECE, 2023)

Synonyms

Maximum residue limits; acceptable daily intake; tolerable weekly intake; maximum levels; tolerance levels; permissible levels; contaminant limits.

Additional scientific description

Food contaminants include toxins and bacteria, but do not include insect fragments, rodent hairs and other extraneous matter. With an estimated 600 million cases of foodborne illnesses annually, unsafe food is a threat to human health, food security, nutrition and economies globally. Ensuring food safety is a public health priority and an essential step to achieving food and nutrition security. Effective national food safety and quality control systems are key not only to safeguarding the health and well-being of people, but also to fostering economic development and improving livelihoods by promoting access to domestic, regional and international markets (FAO/WHO, 2020).

Food poisoning is a form of contamination that can cause severe symptoms and illness, in some instances even becoming life-threatening. Common causes are harmful bacteria (*Bacillus cereus*, campylobacter, cronobacter, *E. coli*, listeria, salmonella, vibrio bacteria, yersinia) and viruses (Norovirus), with fungi, parasites, toxins (Clostridium botulinum) and natural contaminants being less common causes. Symptoms of foodborne illnesses include nausea or vomiting; diarrhoea; allergic reactions; headache; stomach cramps or pains; fever or chills; muscle or joint aches.

Metrics and numeric limits (EU, 2006; FAO/WHO, 2023; WHO, 2024)

Maximum Level: The maximum level for a contaminant in a food or feed commodity is the maximum concentration of that substance recommended by the Codex Alimentarius Commission to be legally permitted in that commodity. There are also national regulations for maximum levels.

Guideline Level: A guideline level is the maximum level of a substance in a food or feed commodity that is recommended by the Codex Alimentarius Commission to be acceptable for commodities moving in international trade. When the guideline level is exceeded, governments should decide whether and under what circumstances the food should be distributed within their territory or jurisdiction.

Note: A contaminant in food or feed is considered a risk for human health when above the maximum/guideline level established by the Codex Alimentarius Commission.

Common contaminants, including relevant Hazard Information Profiles and their limits:

1. Aflatoxins CH0201: EU: 2 µg/kg for aflatoxin B1 in nuts and dried fruits intended for direct human consumption; 4 µg/kg for total aflatoxins (B1, B2, G1, G2) in nuts and dried fruits.

   Codex Alimentarius: 10 µg/kg for total aflatoxins in peanuts intended for further processing; 15 µg/kg for total aflatoxins in other nuts intended for further processing.
2. Lead CH0103 (ICSC 0052, 2019): EU: 0.10 mg/kg in milk; 0.20 mg/kg in fruits and vegetables.

   Codex Alimentarius: 0.01 mg/kg in milk; 0.1 mg/kg in fruits and vegetables.
3. Mercury CH0104 (ICSC 0056, 2019): EU: 0.5 mg/kg in most fish; 1.0 mg/kg in predatory fish like swordfish and tuna.

   Codex Alimentarius: 0.5 mg/kg in most fish; 1.0 mg/kg in predatory fish.
4. Cadmium CH0102 (ICSC 0020, 2005): EU: 0.05 mg/kg in cereals; 0.2 mg/kg in leafy vegetables.

   Codex Alimentarius: 0.1 mg/kg in cereals; 0.2 mg/kg in leafy vegetables.
5. Pesticide Residues CH0501: EU: Varies by specific pesticide and food product (e.g., 0.01 mg/kg for chlorpyrifos in fruits).

   Codex Alimentarius: Varies by specific pesticide and food product (e.g., 0.01 mg/kg for chlorpyrifos in fruits).
6. Dioxins and PCBs (Polychlorinated Biphenyls) CH0502: EU: 1.75 pg/g for dioxins in meat and meat products; 3.5 pg/g for dioxins and dioxin-like PCBs in fish and fish products.

   Codex Alimentarius: Similar limits as the EU for comparable products.

Key relevant UN convention/multilateral treaty

Codex Alimentarius International Food Standards, Codex General Standard for Contaminants and Toxins in Food and Feed (CXS 193- 1995) (FAO/WHO, 2023).

Food and Agriculture Organization of the United Nations (FAO), Joint FAO/WHO Expert Committee on Food Additives (JEFCA) (FAO/WHO, 2024)

United Nations Environment Programme (UNEP), Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (UNEP, 2011).

United Nations Environment Programme (UNEP), Rotterdam Convention on the Prior Informed Consent (PIC) Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (UNEP, 2010).

United Nations Environment Programme (UNEP), Stockholm Convention on Persistent Organic Pollutants (POPs) (UNEP, 2019).

Examples of hazard drivers, impacts and risk management

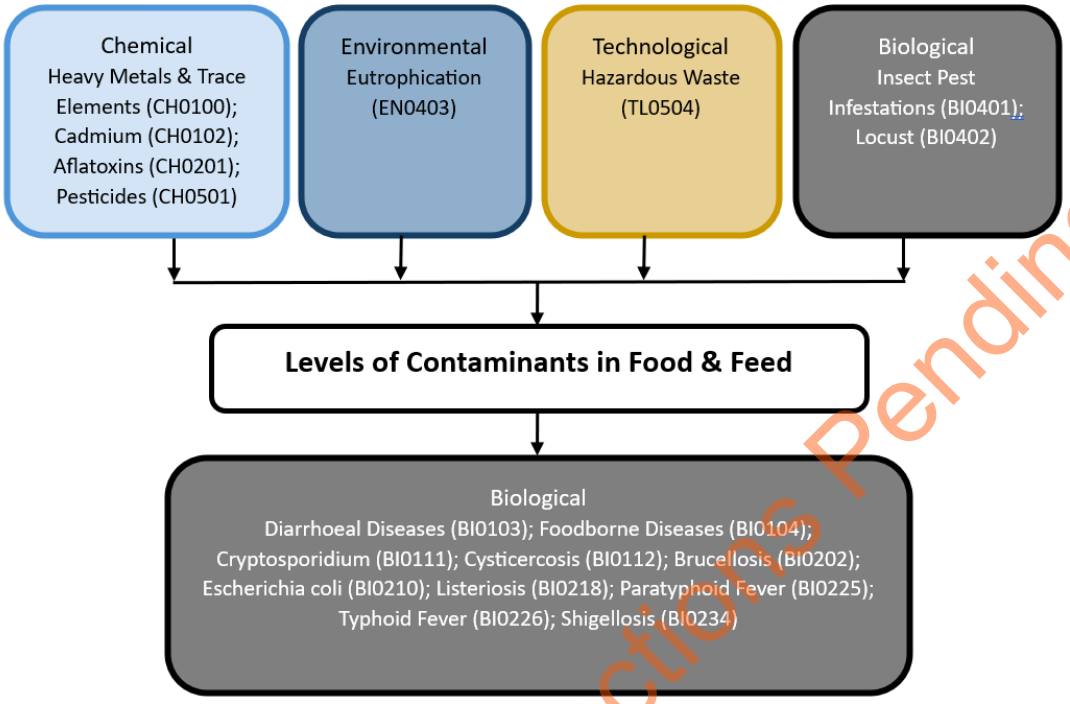
Hazard Drivers include environmental sources such as contaminants from environmental pollution like heavy metals;,or from industrial activities and agricultural run-off containing pesticides and herbicides. Contaminants may also arise during food processing, packaging, or storage, due to inadequate hygiene practices, chemical additives, or unintentional contamination during manufacturing. Some contaminants are naturally occurring, such as mycotoxins, due to fungal growth under specific environmental conditions (HIP CH0201). (EEA, 2024; WHO, 2023)

Impacts include health risks, economic impact and regulatory compliance. Consumption of contaminated food and feed can lead to acute or chronic health effects, including cancer (e.g., from aflatoxins), neurological disorders (e.g. from heavy metals), and reproductive issues. Contamination incidents can result in economic losses due to recalls, market disruptions, and loss of consumer confidence in affected products and brands. Non-compliance with regulatory limits for contaminants can lead to legal consequences, trade restrictions, and sanctions affecting global market access for food and feed products. (CDC, 2024; EC, 2024)

Multi-hazard Context: The figure below summarises common interactions between levels of contaminants in food and feed and

Preliminary – Corrections Pending

other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring levels of contaminants in food and feed. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Ri Data/Information?	Food and Agriculture Organization of the United Nations (FAO); World Health Organization (WHO); food and hygiene agencies
How is the Hazard Observed/Monitored/ Forecast?	Monitoring and testing at various stages of production, processing, distribution a consumption; data collection and analysis; risk assessments and rapid response.

Risk Management: National legislation and a food control system, including food import control, export control, and national monitoring programmes should be implemented. Establishing and monitoring Maximum Residue Limits (MRLs), Acceptable Daily Intakes (ADIs), and other regulatory standards to assess contaminant levels and potential risks. Implementing preventive controls at various stages of the food and feed production chain to minimise contamination risks, including sanitation practices and pest management. Good Agricultural Practices (GAP) should also be applied. (DEFRA, 2009) Developing and implementing rapid response plans for contamination incidents, including product recalls and communication strategies, are examples of corrective actions to mitigate public health risks.

Other measures of risk management include:

- Science-based harmonised texts such as Codex standards, recommendations, guidelines, codes of practice, analytical monitoring, national and international monitoring networks, warning of consumers, and retraction from the market.
- Normative work to support ensuring safe levels of contaminants in food and feed.
- Setting up Food Safety and Quality Programmes (FAO, 2014, FAO, 2024)
- FAO Risk Based Imported Food Control Manual (FAO, 2016)
- Safety risk management

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Coordinating agency or organisation

Joint Food and Agriculture Organization of the United Nations (FAO) / World Health Organization (WHO) Food Standards Program (Codex Alimentarius Commission) for the establishment of food safety standards i.e. MLs for contaminants (quantitative levels above which there is a risk to consumer's health).

Scientific inputs for ML standards setting are provided by the Food and Agriculture Organization of the United Nations (FAO) / World Health Organization (WHO) Expert Committee on Food Additives (JECFA).

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0602 / CHEMICAL / Chemical Hazards in Food and Pharmaceuticals

Substandard and Falsified Medical Products

Definition

Substandard and falsified medical products are defined as those that may cause harm to patients and fail to treat the diseases for which they were intended (WHO, 2018).

Reference

WHO, 2018. Substandard and falsified medical products. World Health Organization (WHO). www.who.int/news-room/fact-sheets/detail/substandard-and-falsified-medical-products Accessed 22 September 2024.

Annotations

GHS Classification (UNECE, 2023)

Synonyms

Counterfeit medicines, Fake medicines

Additional scientific description

Substandard and falsified medical products lead to loss of confidence in medicines, healthcare providers and health systems. They affect every region of the world. Substandard and falsified medical products from all the main therapeutic categories have been reported to the World Health Organization (WHO) and include medicines, vaccines and in vitro diagnostics. Anti-malarials and antibiotics are among the most commonly reported substandard and falsified medical products. Both generic and innovator medicines can be falsified, ranging from very expensive products for cancer to very inexpensive products for the treatment of pain (WHO, 2018).

Substandard and falsified medical products can be found in illegal street markets, via unregulated websites, through to pharmacies, clinics and hospitals. An estimated one in ten medical products in low- and middle-income countries is substandard or falsified. Substandard and falsified medical products contribute to antimicrobial resistance and drug-resistant infections (WHO, 2018).

Falsified medical products may contain no active ingredient, the wrong active ingredient or the wrong amount of the correct active ingredient. They are also commonly found to contain corn starch, potato starch, or chalk. Some substandard and falsified medical products have been found to be toxic with either fatal levels of the wrong active ingredient or other toxic chemicals (WHO, 2018).

Substandard and falsified medical products are often produced in very poor and unhygienic conditions by unqualified personnel and contain unknown impurities and are sometimes contaminated with bacteria (WHO, 2018).

Substandard and falsified medical products are difficult to detect. They are often designed to appear identical to the genuine product and may not cause an obvious adverse reaction, however, they will often fail to properly treat the disease or condition for which they were intended and can lead to serious health consequences including death (WHO, 2018).

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The WHO has adopted definitions of substandard, unregistered/unlicensed and falsified medical products (WHO, 2018):

- Substandard (also called 'out of specification') medical products are authorised medical products that fail to meet either their quality standards or specifications, or both.
- Unregistered/unlicensed medical products are those that have not undergone evaluation and/or approval by the national or regional regulatory authority for the market in which they are marketed/distributed or used, subject to permitted conditions under national or regional regulation and legislation.
- Falsified medical products are those that deliberately/fraudulently misrepresent their identity, composition, or source.

Metrics and numeric limits

Not available.

Key relevant UN convention/multilateral treaty

Not available.

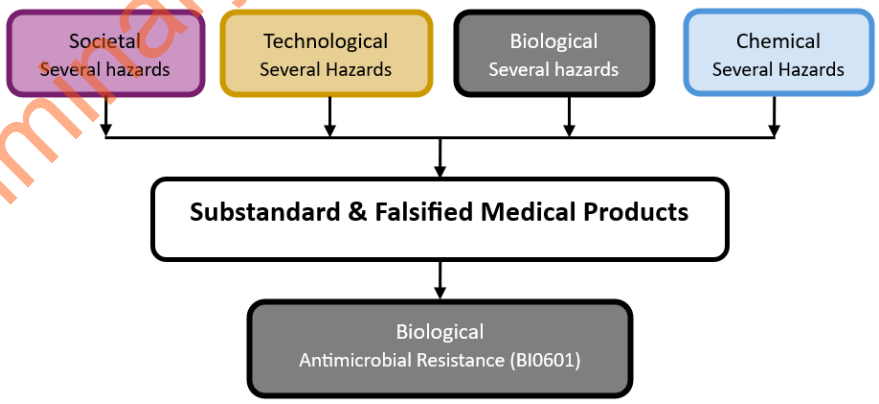
Examples of hazard drivers, impacts and risk management

Hazard Drivers: Many countries and the media frequently report successful action against manufacturers of substandard and falsified medical products. Some reports refer to large-scale manufacturing and others to small back-street operations. With the availability of tableting machines, ovens, specialist equipment, ingredients and packaging materials, clandestine manufacturing facilities are quick and easy to assemble (WHO, 2018).

Impacts: No country remains untouched by this issue, from North America and Europe through to sub-Saharan Africa, South East Asia, and Latin America. What was once considered a problem limited to developing and low-income countries has now become an issue for all. With the exponential increase in internet connectivity, those engaged in the manufacture, distribution and supply of substandard and falsified medical products have gained access to a global marketplace. However, it is in low- and middle-income countries and those in areas of conflict, or civil unrest, where healthcare systems are weak or non-existent that bear the greatest burden of substandard and falsified medical products. Substandard and falsified medical products are most likely to reach patients in situations where there is constrained access to quality and safe medical products, poor governance and weak technical capacity (WHO, 2018).

The falsification of medical products is a crime affecting all regions of the world and addressing it requires greater cooperation along the entire supply chain (WHO, 2017).

Multi-hazard Context: The figure below summarises common interactions between substandard and falsified medical products and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring substandard and falsified medical products. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Informa	World Health Organization (WHO)
How is the Hazard Observed/Monitored/Forecast?	WHO Global Surveillance and Monitoring System

Risk Management: The Member State Mechanism is the global platform where countries can convene, coordinate, decide and

Preliminary – Corrections Pending

organise actions to address substandard and falsified medical products. It was established in order to protect public health and promote access to affordable, safe, efficacious and quality medical products, through effective collaboration between Member States and the WHO to prevent and control substandard and falsified medical products and associated activities (WHO, 2018).

The structured reporting system allows for a fast response to emergencies and the issue of alerts in the most serious cases. It also facilitates in-depth analyses of the medical products most at risk, the vulnerabilities and weaknesses in health systems, the harm caused to public health and the need for investment, training and stronger regulations and standards (WHO, 2018).

The WHO provides guidance (WHO, 2018) for identifying substandard and falsified medical products, both as the products but also for those purchased from the Internet.

- Identifying a substandard or falsified medical product: Some falsified medical products are almost visually identical to the genuine product and very difficult to detect. However, many can be identified by examining the packaging for condition, spelling mistakes, or grammatical errors; checking the manufacture and expiry dates and ensuring any details on the outer packaging match the dates shown on the inner packaging; ensuring the medicine looks correct, is not discoloured, degraded or has an unusual smell; discussing with your pharmacist, doctor or other healthcare professional as soon as possible if you suspect the product is not working properly or you have suffered an adverse reaction; and reporting suspicious medical products to your National Medicines Regulatory Authority.
- Substandard and falsified medical products and the Internet: Unregulated websites, social media platforms, and smartphone applications can also be direct conduits of substandard and falsified medical products. Risks to consumers are significantly increased when obtaining medical products from unlicensed and unregulated sources.

To support countries in enacting or strengthening domestic legislation in this area and in protecting public health, the United Nations Office on Drugs and Crime (UNODC) released a guide to good legislative practices on combating falsified medical product-related crime (UNODC, 2019).

Early Warning Systems In 2013, the WHO launched the Global Surveillance and Monitoring System to encourage countries to report incidents of substandard and falsified medical products in a structured and systematic format, to help develop a more accurate and validated assessment of the problem. The system provides technical support in emergencies, links incidents between countries and regions, and issues WHO medical product alerts; and gathers a validated body of evidence to more accurately demonstrate the scope, scale and harm caused by substandard and falsified medical products and identify vulnerabilities, weaknesses and trends (WHO, 2018).

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Coordinating agency or organisation

World Health Organization (WHO); International Union of Pure and Applied Chemistry (IUPAC).

Preliminary – Corrections Pending

CH0603 / CHEMICAL / Chemical Hazards in Food and Pharmaceuticals

Methanol

Definition

Methanol is a colourless, volatile liquid. Categorized as an alcohol, methanol is commonly used as a solvent and reagent in an array of industrial applications. Outbreaks of methanol poisoning most commonly arise from the consumption of adulterated or informally produced spirit drinks (adapted from NCBI, 2024 and WHO, 2014).

References

NCBI, 2024. PubChem Compound Summary for CID 887, Methanol. National Center for Biotechnology Information (NCBI). https://pubchem.ncbi.nlm.nih.gov/compound/Methanol Accessed 30 Jun 2024.

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Annotations

GHS Classification (UNECE, 2023)

Synonyms

CH_3OH; MeOH; Methyl alcohol; Wood alcohol; Hydroxymethane.

Additional scientific description

Methanol belongs to the class of organic compounds known as primary alcohols. Methanol's chemical formula is CH_3OH and is the simplest aliphatic alcohol, comprising a methyl and a hydroxyl group. It has a role as a solvent and reagent in many industrial processes; it is soluble in water and many organic solvents (NCBI, 2024).

Methanol is a widely available chemical and can be found in various household products, including varnishes, antifreeze, windscreen wash, and fuel for model aircraft. It is also used as a denaturant for ethanol. Globally, approximately 225 million litres of methanol are used each day (WHO, 2014a; WHO, 2014b).

Methanol is primarily produced by catalytic synthesis of synthesis gas (Syngas, a mixture of hydrogen and carbon monoxide) under high-temperature and pressure conditions. Another production method involves the gasification of biomass (Liu, 2023).

Methanol is well-absorbed through the gastrointestinal tract and is also absorbed through the skin and by inhalation. It has a relatively low intrinsic toxicity. However, it is metabolized to highly toxic compounds, including formaldehyde and formic acid, which can cause blindness, central nervous system (CNS) depression, gastrointestinal disturbances, and severe metabolic disturbances that can be life-threatening. Humans have a limited ability to detoxify formic acid, and this metabolite therefore accumulates and causes toxic effects (Nekourar, 2021; WHO, 2014a).

Metrics and numeric limits

Occupational Exposure Limits (OEL) published by the United States Occupational Safety and Health Administration (OSHA) and the European Chemicals Agency (ECA) include a time weighted average (TWA) permissible 8-hour exposure limit of 200 ppm (260 mg/m^3) in air (OSHA, 2023; ECA, 2023).

The toxic dose of methanol varies depending on the individual and on the provision of treatment. Blood methanol concentrations above 0.500 mg/mL are associated with severe toxicity, and concentrations above 1.500-2.000 mg/mL can lead to death in untreated patients. Because patients with methanol poisoning often need intensive medical care, outbreaks of methanol poisoning can rapidly overwhelm medical facilities (WHO, 2014a).

Methanol and its formic acid metabolite were identified in the post-mortem samples of nineteen individuals who were fatally poisoned by methanol consumption during a three-month period in 2022. The compounds were identified in biological fluids (urine, vitreous humour, bile, and cerebral spinal fluid) and tissues (muscle, kidney, liver, spleen, lung, and brain), demonstrating a wide distribution throughout the body of both methanol and formic acid. For methanol, the average concentration range was 2.45-3.36 mg/mL and 2.02-3.42 mg/g for biological fluids and tissues, respectively. For formic acid, the average concentration range was 0.43-2.94 mg/mL and 0.44-0.67 mg/g for biological fluids and tissues, respectively (Tomsia 2022).

Key relevant UN Conventions and multilateral treaties

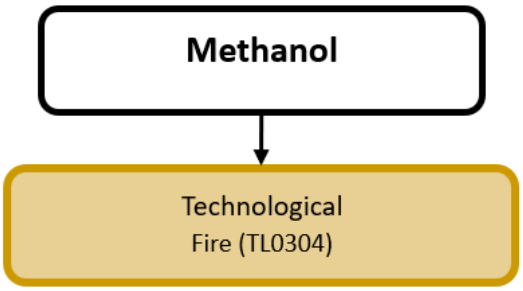
None identified.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: The informal and illicit (undocumented) production of alcoholic drinks is practiced in many parts of the world, including in countries where alcohol is banned. Alcohol produced in this format is not taxed and lacks government and market oversight. Some common names for these drinks include hooch/moonshine (USA), chang'aa/kumi kumi (Kenya), tonto/waragi (Uganda), tuak/tapai (Malaysia), samogon (Russia), and talla (Ethiopia). Such drinks are often sold in unlabelled containers in markets and at illegal drinking venues. Illicitly or informally produced alcohol may also be sold in legitimate bars, particularly in some tourist areas. Some illicitly produced drinks are made to appear legitimate through bottle design and labelling; consumers can be misled into believing that they are buying a genuine brand of alcohol. Bottles may be sold in shops, markets and bars, often at what appears to be a discounted price (Manning, 2021; WHO, 2014a).

Impacts: Outbreaks of methanol poisoning arise from the consumption of adulterated counterfeit or informally produced spirit drinks. There have been a multitude of outbreaks between 1963-2020, including in the following countries: Bangladesh, Botswana, Cambodia, Canada, China, Costa Rica, Czech Republic, Dominican Republic, Ecuador, El Salvador, Estonia, Haiti, Honduras, India, Indonesia, Iran, Italy, Kenya, Libya, Madagascar, Malaysia, Mongolia, Nicaragua, Nigeria, Norway, Pakistan, Papua New Guinea, Poland, Russia, Saudi Arabia, Serbia, Spain, Sudan, Taiwan, Tunisia, Turkey, and Uganda. The size of these outbreaks has ranged from 10 to greater than 800 victims, with hundreds of hospitalizations and fatalities occurring within individual outbreaks in some instances (Eskandrani, 2022; Manning, 2021; Tomsia, 2022).

Multi-hazard Context: The figure below summarises common interactions between methanol and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring methanol. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Preliminary – Corrections Pending

Which institution(s) produce(s) Disast Data/Information?	World Health Organization (WHO)
How is the Hazard Observed/Monitor Forecast?	Monitoring emergency rooms and hospitals for cases of methanol poisoning and recording of si and symptoms of methanol consumption Centralized data collection and rapid reporting system, e.g., in the hospital setting and at poisor control centres to facilitate ease of communication between health agencies and public health officials

Risk Management: The WHO guidance on methanol poisoning outbreaks (WHO, 2014a) recommends the following risk management for prevention and control:

What can individuals do to protect themselves?

- Refrain from purchasing or producing illegal alcoholic drinks.
- Be suspicious about alcoholic drinks offered for sale in informal settings that are not licensed to sell alcohol, such as market stalls, and/or that are offered at a cheap price.
- Do not buy alcoholic drinks sold in unlabelled containers.
- Check branded products for labels that are poorly printed or with typographical errors, or bottles with broken seals. Do not buy these.
- Be aware of the symptoms of methanol poisoning and seek medical attention immediately if exposure is suspected.

What measures can countries take?

- Put in place a national strategy and legal framework to reduce the harmful use of alcohol.
- Use public health campaigns to promote awareness of the dangers of informally produced and illicit alcoholic drinks. These can be targeted towards particular high-risk groups, such as alcohol-dependent individuals and tourists.
- Since early recognition of an outbreak is vital to improve outcomes, ensure that medical professionals are trained in the diagnosis and management of methanol poisoning.
- Where mass methanol poisonings have the potential to occur, establish a protocol for the management of these outbreaks.
- The ability of laboratories to undertake blood methanol analysis can help identify and guide the clinical management of poisoned patients.
- Ensure accessible and affordable treatment is available for all, including antidotes (e.g., fomepizole, ethanol).
- Provide support to victims, particularly those at risk of recurrent events, such as alcohol-dependent individuals.

The WHO is committed to reducing the health burden resulting from the harmful use of alcohol (WHO, 2014b). In 2010, the World Health Assembly endorsed a global strategy to reduce the harmful effects of alcohol. Ten recommended target areas were identified, including one addressing the need to reduce the public health impact of illicit alcohol and informally produced alcohol. Several policy options and interventions are suggested, including: developing good quality control with regard to production and distribution of alcoholic beverages; regulating sales of informally produced alcohol and bringing it into the taxation system; creating an efficient control and enforcement system, including tax stamps; developing or strengthening tracking and tracing systems for illicit alcohol; ensuring necessary cooperation and exchange of relevant information on combating illicit alcohol among authorities at national and international levels; and issuing relevant public warnings about contaminants and other health threats from informal or illicit alcohol (WHO, 2014b).

Critical elements of Early Warning Systems for methanol poisoning should involve several components to detect and respond to potential outbreaks, especially in contexts where methanol poisoning is a recurrent issue.

- Provision of training for healthcare professionals to recognize and treat methanol poisoning.
- Monitoring emergency rooms and hospitals for cases of methanol poisoning and recording of signs and symptoms of methanol consumption.
- Creating a centralized data collection and rapid reporting system, e.g., in the hospital setting and at poison control centres, to facilitate ease of communication between health agencies and public health officials.
- Rapid testing of biological specimens from individuals suspected of methanol intoxication.
- Rapid testing of contaminated alcohol samples.
- Issuing public warnings and health advisories through mainstream media and social media platforms. Educating the public about the dangers of consuming non-commercial/unregulated alcohol products and recognizing the symptoms of methanol poisoning.
- Creating platforms for the public to report symptoms of potential poisonings electronically and the ability to receive

Preliminary – Corrections Pending

immediate advice from a healthcare professional.

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Coordinating agency or organisation

World Health Organization (WHO).

International Union of Pure and Applied Chemistry (IUPAC

Preliminary – Corrections Pending

CH0604 / CHEMICAL / Chemical Hazards in Food and Pharmaceuticals

Opioids and Other Psychoactive Substances

Definition

Psychoactive substances are chemical compounds that can lead to physical or psychological dependence when consumed repeatedly, often altering brain function and behaviour. Overdose and overuse have caused significant public health concerns due to their potential to cause a wide range of adverse health effects. Addictive substances include alcohol, nicotine, (synthetic) opioids, (natural) opiates, stimulants, and certain sedatives, amongst others.

Reference

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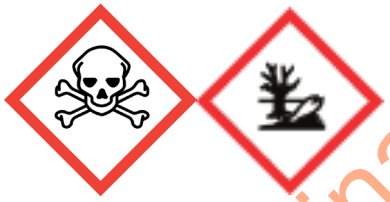
Preliminary – Corrections Pending

Annotations

GHS Classification (UNECE, 2023)



Synonyms

Ethanol, nicotine (3-[(2S)-1-methylpyrrolidin-2-yl]pyridine)

Additional scientific description

Opiates are drugs derived from opium, which are alkaloids naturally found in the opium poppy plant Papaver somniferum that upon extraction typically yield (-)-morphine (10-15%), (-)-codeine (3-methylmorphine, 3-4%), and (-)-thebaine (1-2%). On the other hand, the term opioids is used for all substances, either natural or synthetic, that bind to opioid receptors, including the antagonists (NIDA, 2024).

These substances have been consumed as medicine for the treatment of pain, but also recreationally for the euphoria and hallucinations that they provoke. The uncontrolled use of these substances (opioid overdose) has resulted in the present so-called “opioid” epidemic, responsible for around 80% of the 600,000 deaths reported worldwide in 2019. Common side effects include tolerance and dependence, itching, pupil constriction, constipation, nausea and vomiting, and, most importantly, respiratory depression. The major offenders are synthetic opioids other than methadone, followed by psychostimulants, and finally heroin (WHO, 2023).

Heroin, an acetylated derivative of morphine, was first made in 1874 and later first manufactured in 1898. The acetylation makes the molecule less polar than morphine, so that it crosses the Blood Brain Barrier (BBB) more easily, and once inside the brain, enzymes hydrolyse the esters quite easily resulting in a faster delivery of morphine, which is the actual drug responsible

for the observed intense euphoric effects (NIDA, 2011)

Prescription opioids are the leading offenders in drug addiction by several mechanisms, such as redirection, over-prescription, or doctor shopping (Skolnick, 2018). Some prescription opioids include hydrocodone bitartrate, oxycodone hydrochloride, oxymorphone hydrochloride, morphine sulfate extended-release, and codeine. One of the main contributors has been the oxycodone hydrochloride pills, where over-prescription of opioids leads to overdoses and addiction.

Other less common and simpler opioids are the morphinans, which are more potent and longer lasting than their morphine counterparts, with a higher toxicity. Included in the simpler structures, made by simplification strategies, are the 6,7-benzomorphans (Metazocine/Pentazocine), the 4-phenylpiperidines, and methadone, which is used to treat drug addicts.

One of the opioids of most recent concern, by its potency and overwhelming abuse, is fentanyl and its many analogues. Fentanyl was first synthesized in the early 1960s and is 50-100 times more potent than heroin, 2-3 mg of the opioid can be fatal (Stanley, 2005).

When used under strict medical supervision, fentanyl is safe and appropriate. Fentanyl use mainly relies on treating patients who have become tolerant to opioid therapy for cancer pain and need something stronger. The range of compound amount typically used can be between 50 – 1200 µg (mcg) in different forms of delivery or concentrations. Among the fentanyl approved drugs, we should mention the transdermal patches, sublingual tablets, lollipops, and the injectable forms. The use of fentanyl in colonoscopy studies (25-50 µg) is also common, safe, and significantly shortens recovery times (Stanley, 2005).

Misuse of fentanyl sparked by the illicit market has led to the detection of several forms of the drug, mainly as illegal pills, in different forms and combinations. The ease of synthesizing the derivatives coupled with the proliferation of clandestine laboratories with no quality control has resulted in haphazard combinations of the drug and millions of deaths. Derivatives of considerable importance include furanyl fentanyl, acetylfentanyl, fluorofentanyl (different ring substitutions with the para derivative being more abused), and the extremely potent carfentanil, among many others. Carfentanil, by itself, is an animal tranquilizer 100 times more potent than fentanyl and 10,000 times more potent than morphine, and is used in veterinary medicine for the immobilization of large animals such as rhinoceros or elephants. Unfortunately, it has also found its way into street drugs. WHO continues to monitor several fentanyl analogues through its surveillance system for new psychoactive substances, alerting countries to the potential dangers associated with these substances (Han, 2019).

More recently, fentanyl and xylazine combinations have been detected in the streets, which has become an emerging threat since July 2023. Xylazine is used in veterinary medicine (mainly with horses) as an anaesthetic, but its misuse in humans causes euphoric effects, muscle relaxation, and trouble breathing. In addition, users can develop chronic wounds that are difficult to heal and painful. Xylazine is an Alpha-2 agonist, not an opioid, and as such, naloxone does not reverse its effects. Presently, there is no approved antagonist that can reverse its deleterious effects. Other opioids, such as nitazines, are also dangerous, as is accidental or deliberate contamination of heroin by fentanyls or nitazenes, which can lead to unexpected toxicity and accidental overdose (Jain 2024).

Alcohol and nicotine are two widely used substances with addictive properties that can have severe consequences for health and well-being. Alcohol is a depressant that enhances the release of dopamine in the brain, creating feelings of relaxation and euphoria. Chronic use can lead to tolerance, dependence, and withdrawal symptoms such as anxiety, tremors, and seizures. Long-term alcohol misuse increases the risk of liver disease, cardiovascular and neurological damage (NIAAA, 2021).

Nicotine, found in tobacco products, is a highly addictive stimulant that rapidly affects the brain, triggering the release of dopamine and reinforcing the habit. Prolonged use of nicotine leads to dependence and withdrawal symptoms like irritability, anxiety, and cravings. It is a major risk factor for respiratory diseases, heart disease, and various cancers, particularly lung cancer. The addictive nature and health risks of both substances underscore the need for effective prevention and support for individuals seeking to overcome their use (Benowitz , 2010).

Metrics and numeric limits

Opioids: Prescription Guidelines

1. **Morphine Milligram Equivalents (MME):** The Centers for Disease Control and Prevention (CDC) recommends avoiding doses of **≥90 MME/day** for chronic pain when possible, as higher doses increase the risk of overdose. (CDC, 2022).
2. **Duration of Use:**
    1. For acute pain, prescriptions should generally not exceed **3-7 days**, as longer durations significantly increase the risk of dependency (Dowell, 2016).
    2. **Naloxone Prescription:** Co-prescription of naloxone is recommended for patients at higher risk of opioid overdose, such as those on **≥50 MME/day** (Dowell, 2016).

Alcohol: Moderate Drinking Guidelines:

1. **United States Dietary Guidelines (2020-2025):**

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- Moderate drinking is defined as:
  - **Up to 1 drink per day for women.**
  - **Up to 2 drinks per day for men.**
  - One standard drink is: **14 grams of pure alcohol**, equivalent to:
    - 12 oz of beer (5% alcohol).
    - 5 oz of wine (12% alcohol).
    - 1.5 oz of distilled spirits (40% alcohol). (U.S. Department of Health and Human Services, 2020).

2. **Weekly Limits:**
   - The National Institute on Alcohol Abuse and Alcoholism (NIAAA) suggests: **No more than 7 drinks per week for average women** and **14 drinks per week for average men** to reduce risks of alcohol-related harm (NIAAA, 2021). Women who are pregnant or planning a pregnancy should not drink alcohol.

Key relevant UN convention/multilateral treaty

Several key United Nations conventions and multilateral treaties address issues related to the control of addictive substances such as opioids, alcohol, and nicotine. Here's an overview:

Opioids:

- **Single Convention on Narcotic Drugs (1961, as amended in 1972):** Establishes international control over narcotic drugs, including opioids, to limit their use to medical and scientific purposes while preventing illicit production and trafficking. Administered by the International Narcotics Control Board (INCB).
- **Convention on Psychotropic Substances (1971):** Aims to control psychotropic substances, including certain synthetic opioids, to prevent misuse while ensuring their availability for legitimate purposes.
- **United Nations Convention against Illicit Traffic in Narcotic Drugs and Psychotropic Substances (1988):** Strengthens international cooperation to combat illicit drug trafficking, focusing on opioids and their precursors.

Alcohol: No specific global treaty regulates alcohol in the same way as narcotics, but alcohol is indirectly addressed under health and public policy frameworks:

- **Global Strategy to Reduce the Harmful Use of Alcohol (2010):** A non-binding framework by the World Health Organization (WHO) encouraging member states to implement policies addressing alcohol misuse.
- **WHO Framework Convention on Tobacco Control (2003):** Although focused on tobacco, this treaty includes measures related to the dual use of substances like alcohol and tobacco, recognizing the intersection of public health challenges.

Nicotine (Tobacco): WHO Framework Convention on Tobacco Control (FCTC, 2003): The first legally binding health treaty under WHO, focusing on reducing tobacco consumption and exposure to nicotine products. Includes measures on advertising bans, tax policies, and restrictions on public smoking.

Examples of hazard drivers, impacts and risk management

Hazard Drivers for Opioid Dependence: There are a number of risk factors for opioid overdose as described by WHO (WHO, 2023). These include:

- Having an opioid use disorder;
- Taking opioids by injection;
- Resumption of opioid use after an extended period of abstinence (e.g. following detoxification, release from incarceration, cessation of treatment);
- Using prescription opioids without medical supervision;
- High prescribed dosage of opioids (more than 100 mg of morphine or equivalent daily).
- Using opioids in combination with alcohol and/or other substances or medicines that suppress respiratory function, such as benzodiazepines, barbiturates, anaesthetics, or some pain medications; and
- Having concurrent medical conditions such as HIV, liver or lung diseases or mental health conditions.

Males, people of older age and people with low socio-economic status are at higher risk of opioid overdose than women, people of young age groups and people with higher socio-economic status.

Hazard Drivers for Alcohol Dependence (Mustafa 2024)**:**

A. Biological and Genetic Factors
   1. Family History of Addiction: Having a parent or close relative with alcohol addiction increases the risk due to genetic predisposition.

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2. Neurochemical Imbalances: Altered levels of neurotransmitters, such as dopamine, can make individuals more susceptible to addiction.
3. Early Onset of Drinking: Initiating alcohol consumption at a young age is linked to a higher risk of developing dependence.

B. Psychological Factors

1. Mental Health Disorders: Conditions like depression, anxiety, or PTSD often coexist with alcohol misuse.
2. Stress and Coping Mechanisms: Using alcohol as a coping mechanism for stress increases the risk of dependency.

C. Social and Environmental Factors

1. Peer Pressure: Strong influence from peers can lead to habitual alcohol use.
2. Cultural Norms: Societal attitudes that normalize or glamorize drinking can increase risk.
3. Availability and Accessibility: Easy access to alcohol significantly raises the likelihood of abuse.

D. Other Factors

1. Trauma and Adverse Childhood Experiences (ACEs): Early-life trauma is strongly associated with addiction risks.
2. Lack of Education: Poor understanding of the risks associated with excessive alcohol consumption can contribute.

Hazard Drivers for nicotine dependence (Benowitz 2010)**:**

A. Biological and Genetic Factors

1. Genetic Susceptibility: Genetic variations can affect how the body processes nicotine and the likelihood of addiction.
2. Adolescent Brain Development: Young brains are particularly sensitive to the effects of nicotine, increasing addiction risks.

B. Psychological Factors

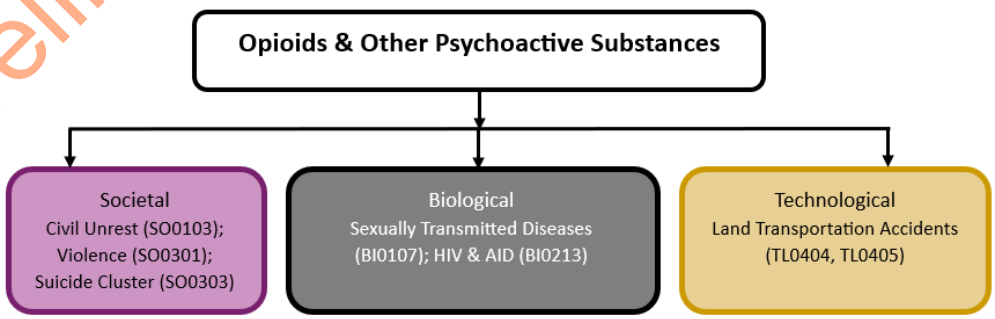
1. Coexisting Mental Health Conditions: Anxiety and depressive disorders are common among individuals with nicotine dependence.
2. Impulsivity and Sensation-Seeking: Personality traits that favour risky behaviours are linked to higher nicotine use.

C. Social and Environmental Factors

1. Peer and Social Influence: Adolescents are particularly vulnerable to smoking due to peer pressure.
2. Marketing and Advertising: Targeted advertisements and media representations glamorizing smoking contribute significantly.
3. Family Smoking Habits: Exposure to smoking within the household normalizes the behaviour and increases risk.

Impacts: Opioids are the deadliest drug type. According to the US Drug Enforcement Administration (DEA) seven out of ten illegal fake pills in the streets with fentanyl contain a potentially lethal dose (at least 2 mg of fentanyl). Drug traffickers are using fake pills to exploit the opioid crisis and prescription drug misuse. In 2022, an estimated 110,757 people died by drug poisoning in the United States. Fentanyl, the synthetic opioid most found in fake pills, is the primary driver in this alarming increase in poisoning deaths. According to WHO estimates, approximately 125,000 people died of opioid overdose in 2019.

Multi-hazard Context: The figure below summarises common interactions between opioids & other addictive substances and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: No Information Available

Risk management: Detection of fentanyl is difficult since it has no taste, no smell, and cannot be distinguished by touch. Some recent detection efforts include fentanyl test strips (FTS) and advanced handheld Raman spectrometers analysers such as Tactic ID or TruNarc™, which are narcotic analysers. Portable mass spectrometers may also prove useful. FTS are small strips of paper that can detect the presence of fentanyl in different kinds of drugs and drug forms and can inform people about the presence of fentanyl so they can take steps to reduce their risk of overdose. There is also a commercial strip version that

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combines both fentanyl and xylazine in one test strip. The Raman spectrometers allow the first responders to quickly and accurately identify key drugs of abuse anywhere at any time without opening the containers (Crocombe 2023).

Uncontrolled opioid use can lead to dependence, both physical and mental. There are observable withdrawal symptoms and a sustained mental need for the drug or substance. An overdose needs immediate attention due to its fatal consequences. The best is the use of an antidote; more commonly now used is naloxone, which is an antagonist of the opioid receptors and reverses the overdose (van Dorp, 2007). Naloxone comes in different forms, but the most common is the nasal spray with similar action times as an intramuscular injection. Sometimes several doses are needed to reverse a strong opioid overdose. WHO recommends that naloxone be made available to people likely to witness an opioid overdose, as well as training in the management of opioid overdose. More recently, in the US, a similar delivery method has been manufactured with Nalmefene with the advantage of having a longer half-life (11.4 hrs) vs. 1.2 hrs than naloxone (Green 2024).

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WHO recommends the use of a range of treatment options for opioid dependence. These include opioid agonist maintenance treatment (with medicines such as methadone and buprenorphine), which has the strongest evidence of effectiveness and cost-effectiveness, as well as psychosocial treatment and support, and pharmacological treatment with opioid antagonists (such as naltrexone).

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Coordinating agency or organisation

World Health Organisation (WHO)

International Union of Pure and Applied Chemistry (IUPAC)

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CH0605 / CHEMICAL / Chemical Hazards in Food and Pharmaceuticals

Marine Toxins

Definition

Marine toxins (biotoxins) are naturally occurring, toxic substances, mostly caused by certain types of marine organisms, such as toxic algae, but also by bacteria. These toxins can accumulate in fish and shellfish, causing significant public health concerns due to their potential to cause a wide range of adverse health effects.

Reference

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Annotations

GHS Classification (UNECE, 2023)

Synonyms

Algal bloom toxins; biotoxins; ichthyotoxins; phycotoxins; seafood toxins; shellfish toxins.

Additional scientific description

Marine toxins are primarily produced by algae or bacteria and are concentrated in contaminated fishery and aquaculture products. When people consume these contaminated products, depending on the toxin, the symptoms can be diarrheic, paralytic, amnesic, or neurologic, some of which result in high mortality and long-term morbidity (Sobel and Painter, 2005).

Routine clinical diagnostic tests are not available for these toxins; diagnosis is based on clinical presentation and a history of eating fishery and aquaculture products in the preceding 24 hours (Sobel and Painter, 2005). There is no antidote for any of the marine toxins, and supportive care is the mainstay of treatment. Paralytic shellfish poisoning and puffer fish poisoning can cause death within hours of consuming the toxins and may require immediate intensive care (Sobel and Painter, 2005).

A Joint FAO/IOC/WHO expert meeting classified the toxins into eight groups based on their chemical structure (FAO/WHO, 2016): the Azaspiracid (AZA) group, Brevetoxin group, Cyclic Imines group, Domoic Acid (DA) group, Okadaic Acid (OA) group, Pectenotoxin (PTX) group, Saxitoxin (STX) group, and Yessotoxin (YTX) group.

The Food and Agriculture Organization of the United Nations (FAO) reports that they can also be classified by the type of poisoning they cause (FAO, 2004):

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Paralytic shellfish poisoning (PSP) (FAO, 2004)**:** PSP poisoning in humans is caused by ingestion of shellfish containing PSP toxins, which accumulate by shellfish grazing on algae producing these toxins.

- **Symptoms:** slight tingling or numbness to complete respiratory paralysis.
- In fatal cases, respiratory paralysis occurs within 2 to 12 hours of consuming the PSP-contaminated food.

Diarrhoeic shellfish poisoning (DSP) (FAO, 2004): In humans, DSP poisoning is caused by the ingestion of contaminated bivalves such as mussels, scallops, oysters, or clams. The fat-soluble DSP toxins accumulate in the fatty tissue of the bivalves.

- **Symptoms:** diarrhoea, nausea, vomiting and abdominal pain starting 30 minutes to a few hours after ingestion and complete recovery occurs within three days.
- DSP toxins can be divided into different groups depending on chemical structure - the first group, acidic toxins, includes okadaic acid and its derivatives named dynophysistoxins; the second group, neutral toxins, consists of polyether-lactones of the pectenotoxin group; the third group includes a sulphated polyether and its derivatives the yessotoxins.

Amnesic shellfish poisoning (ASP) (FAO, 2004): In humans, ASP is also known as domoic acid poisoning (DAP) because amnesia is not always present.

- **Symptoms:** abdominal cramps, vomiting, disorientation and memory loss (amnesia).
- The causative toxin (the excitatory amino acid domoic acid or DA) was produced by the diatom species Pseudo-*nitzschia pungens f. multiseries* (*Nitzschia pungens f. multiseries*).

Neurotoxic shellfish poisoning (NSP) (FAO, 2004): NSP is caused by polyether brevetoxins produced by the unarmoured dinoflagellate *Gymnodinium breve* (also called *Ptychodiscus breve*, since 2000 called *Karenia brevis*) are toxic to fish, marine mammals, birds, and humans, but not to shellfish.

- An unusual feature of G. breve is the formation by wave action of toxic aerosols, which can lead to asthma-like symptoms in humans.

Azaspiracid shellfish poisoning (AZP) (FAO, 2004): In November 1995, at least eight people in the Netherlands became ill after eating mussels (*Mytilus edulis*) cultivated at Killary Harbour, Ireland. Although the symptoms resembled those of diarrhoeic shellfish poisoning (DSP), concentrations of the major DSP toxins were very low.

- The known organisms producing DSP toxins were not observed in water samples collected at that time.
- In addition, a slowly progressing paralysis was observed in the mouse assay using the mussel extracts. These neurotoxic symptoms were different from typical DSP toxicity.
- It was then that azaspiracid (formerly called Killary Toxin-3 or KT3) was identified and the new toxic syndrome was called azaspiracid poisoning (AZP).

Ciguatoxins causing ciguatera poisoning (CP) (FAO, 2004): The name ciguatera was given by Don Antonio Parra in Cuba in 1787 to intoxication following ingestion of the 'cigua', the Spanish trivial name of a univalve mollusc, Turbo pica, reputed to cause indigestion.

- The term cigua was somehow transferred to an intoxication caused by the ingestion of coral reef fish species.
- The causative toxins, the ciguatoxins, accumulate through the food chain, from small herbivorous fish grazing on the coral reefs to organs of the bigger carnivorous fish that feed on them.

Metrics and numeric limits (FAO/WHO, 2015)

The maximum level per kilogram of mollusc flesh for the different toxin groups is as follows:

- **Saxitoxin (STX) group:** ≤ 0.8 mg of saxitoxin equivalent
- **Okadaic acid (OA) group:** < 0.16 mg of okadaic acid equivalent
- **Domoic acid (DA) group:** < 20 mg of domoic acid
- **Brevetoxin (BTX) group:** < 200 mouse units or equivalent
- **Azaspiracid (AZA) group:** < 0.16 mg

Key relevant UN convention/multilateral treaty

Food and Agricultural Organisation of the United Nations (FAO) and World Health Organisation (WHO), The Codex Alimentarius Commission (CAC) (FAO/WHO, 2024)

United Nations Environment Programme (UNEP), The Convention on Biological Diversity (CBD) (CBD, 2024)

International Maritime Organisation, The International Convention for the Prevention of Pollution from Ships (MARPOL) (IMO, 1973)

United Nations Environment Programme (UNEP), Stockholm Convention on Persistent Organic Pollutants (POPs) (UNEP, 2019).

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United Nations Oceans & Law of the Sea (UNOLS), The United Nations Convention on the Law of the Sea (UNCLOS) (UNOLS, 1982)

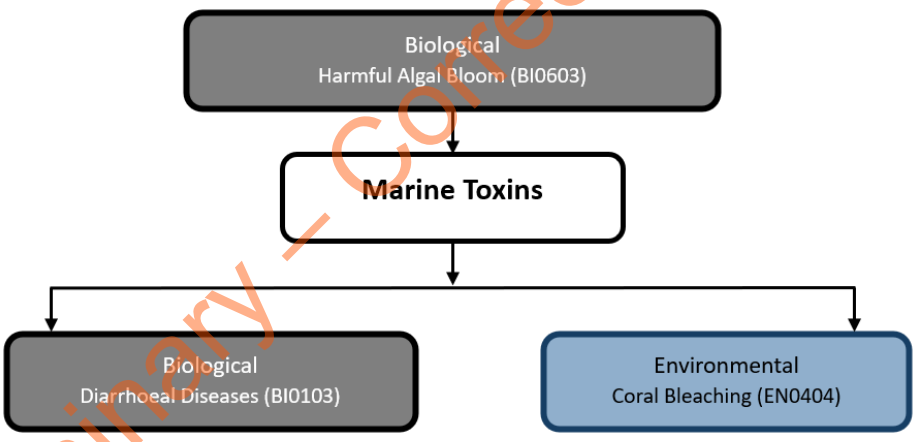
Examples of hazard drivers, impacts and risk management

Hazard Drivers: The substantial increase in the consumption of fishery and aquaculture products in recent years, together with globalisation of trade, has increased the potential for human exposure to these marine biotoxins. Monitoring programmes for the toxins and their source organisms, and rapid notification of food safety issues by the authorities is essential to avoid foodborne intoxications. Toxic cyanobacteria can also occur in freshwater, affecting water supplies (He 2016). Extensive environmental monitoring and sometimes seasonal quarantine of a harvest are used to reduce the risk of exposure (Sobel and Painter, 2005).

It is difficult to predict when a bloom will develop. Climatic and environmental conditions, such as changes in salinity, rising water temperature, increased nutrient levels and sunlight, can influence population growth. Other drivers of marine toxins include climate change and ballast water discharge. Rising sea temperatures and changes in ocean circulation patterns cause warmer temperatures and altered currents can enhance algal growth and toxin production (EPA, 2024). Ships discharging ballast water into oceans and seas introduce non-native, potentially toxic algal species into waters (IMO, 2019). Excessive nutrients can also lead to the proliferation of toxin-producing algae (NOS, 2023).

Impacts of marine toxins include human health effects such as gastrointestinal, neurological, and cardiovascular issues and in severe cases, death. Marine and freshwater ecosystems are also affected, including disruption of food webs, fish kills, and loss of biodiversity. Economic impacts include loss of revenue from fisheries, tourism, and aquaculture, as well as increased public health costs (FAO, 1999).

Multi-hazard Context: The figure below summarises common interactions between marine toxins and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring marine toxins. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	European Commission (EC); National Oceanic and Atmospheric Administration (NOAA); environmental agencies
How is the Hazard Observed/Monitored/Foreca	Monitoring and remote sensing; prediction modelling; communication

Risk Management includes the establishment of national monitoring programmes for marine biotoxins and their source organisms, by methods such as regular sampling and testing of water and seafood for toxins, and their continuous update to include new and emerging toxins when necessary (WHO, 2017). Implementing regulatory limits and standards, as well as informing the public about risks and safe consumption practices, are risk management protocols that should be implemented. Other mitigation strategies include reducing nutrient runoff through best management practices (BMPs) in agriculture, and improving sewage treatment; also reducing greenhouse gas emissions, protecting marine environments (EPA, 2023; UNCC, 2024).

Preliminary – Corrections Pending

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Preliminary – Corrections Pending

Coordinating agency or organisation

Food and Agriculture Organization of the United Nations (FAO), World Health Organization (WHO)

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0901 / CHEMICAL / Other Chemical Hazards

Corrosive Substances

Preliminary – Corrections Pending

Definition

Corrosive substances are materials, such as strong acids and strong bases, that, through chemical reactions, cause visible destruction of biological tissues and other materials. Acids are substances that have a high tendency to donate protons when completely dissociating into ions in water, whereas strong bases are substances that accept protons when completely dissociating into ions in water. Both are highly corrosive and catalyse the decomposition of biological molecules. (Burrows et al., 2021)

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Annotations

GHS Classification (UNECE, 2023)

Synonyms

Mineral acids; inorganic acids; strong inorganic acids; highly acidic solutions; Lewis acid; electron-pair acceptor; powerful bases; alkalis; caustic bases; highly basic compounds; Lewis base; electron-pair donor.

Additional scientific description

Both acids and bases can cause major public harm. They are both principally corrosive because they catalyse hydrolysis reactions and other nucleophilic substitution reactions that result in the decomposition of biological molecules. (Brown, 2018; Burrows et al., 2021; McMurry, 2004; Wade and Simek, 2022) Acids are chemical species that are capable of donating a proton (Bronsted Acid) or capable of forming a covalent bond with an electron pair (Lewis Acid). (IUPAC, 2014) The dissociation process of strong acids almost goes to completion, meaning almost all of the acid molecules break apart into ions, producing high concentrations of hydronium ions that can initiate undesirable chemical reactions. This characteristic is in contrast to weak acids, which only partially dissociate in water. (Wade and Simek, 2022) Examples of strong acids include hydrochloric acid, nitric acid (ICSC 0183, 2016), perchloric acid (ICSC 1006, 2000) and sulphuric acid (ICSC 0362, 2016).

Bases are chemical species that have an available pair of electrons capable of forming a covalent bond with a proton (Brønsted base) or with the vacant orbital of some other species (Lewis base). (IUPAC, 2014) The dissociation process of strong bases goes to completion, producing high concentrations of hydroxide ions. They have a high affinity for accepting protons which fully neutralises them. The strength of the base is measured by its ability to donate hydroxide ions in solution. Lewis theory defines a strong base as an electron pair donor, making them effective at forming bonds with electron-deficient species. (Atkins & Jones, 2010; Burrows et al.,2021; McMurry et al., 2004; Wade and Simek, 2022) Examples of strong bases include caesium hydroxide (ICSC 1592, 2006), calcium hydroxide (ICSC 0408, 1997), lithium hydroxide (ICSC 0913, 2009), potassium hydroxide (ICSC 0357, 2010) and sodium hydroxide (ICSC 0360, 2010).

Lewis acids are electron-pair acceptors that are able to react with a Lewis acid base to form a Lewis adduct, by sharing the electron pair donated by the Lewis base. (IUPAC, 2014)

$$Lewis\ Acid + Lewis\ Base \rightarrow Lewis\ Adduct$$

Acids and bases can form conjugate acid-base pairs, where the acid formed on protonation of a base is called the conjugate acid, and the base is the conjugate base. The conjugate acid always carries one unit of positive charge more than the base, but the absolute charges of the species are immaterial to the definition. (IUPAC, 2014h) Strong acid-base reactions are typically exothermic - the new bond formed between the proton and the base is stronger than the bond that was broken to release the proton, therefore, the released energy raises the temperature of the surroundings. The strength of an acid is inversely proportional to the strength of its conjugate base - i.e. the conjugate base of a strong acid must be a weak base; and the conjugate base of a weak acid must be a strong base. In the reaction of an acid with a base, the equilibrium generally favours the weaker acid and base. (Wade and Simek, 2022)

Metrics and numeric limits (Brown et al., 2018; IUPAC, 2014; McMurry et al., 2004)

Metrics are used to quantify the strength of acids, including their pH, pOH, pK_a, and pK_b; acidity/ionisation constants (K_a, K_b, and K_w); degree of dissociations; and concentrations. pH (equation 1) is a measure of how acidic or alkaline a substance is, ranging (for aqueous solutions) from 0 (strongly acidic) to 14 (strongly basic).

$$pH + pOH = 14 \qquad \textbf{Equation 1}$$

Strong acids have high concentrations of hydronium ions, typically giving low pH values close to zero when fully dissociated in water. The pK_a (equation 2) is a measure of the concentration of hydrogen ions when there are equal concentrations of both the ionised and unionised form of a substance. Strong acids also tend to have pK_a values below zero due to their equilibrium lying to the far right, resulting in negligible concentrations of undissociated acid. Whereas strong bases have high concentrations of hydroxide ions, typically giving high pH values close to 14 when fully dissociated in water. The pOH is a measure of the concentration of hydroxide ions in a solution. Strong bases also tend to have pOH values close to zero.

$$pK_a + pK_b = pK_w \qquad \textbf{Equation 2}$$

The acidity constant (K_a equation 3) is another equilibrium constant for splitting off a proton from a charged or uncharged acid. This metric is usually very high for a strong acid, indicating complete dissociation. (IUPAC, 2014) Due to this dissociation, the concentrations are also typically very high.

$$K_a K_b = K_w \qquad \textbf{Equation 3}$$

The ionisation constant is another equilibrium constant for quantifying the extent to which a base ionises in solution. This metric is usually very large for a strong base, indicating complete ionisation. The degree of dissociation is how much the strong base completely dissociates into ions when dissolved in water, producing hydroxide ions. Acids can be neutralised by strong bases, producing water and salt during the vigorous reaction. This is due to the high concentration of hydroxide ions, giving an overall high concentration for a strong base.

Key relevant UN convention / multilateral treaty

Occupational Safety and Health Administration (OSHA), Chemical Hazards and Toxic Substances: Controlling Exposure. (OSHA, 2024)

European Union (EUR), The Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) Regulation. (EUR-Lex, 2023)

United Nations Environment Programme (UNEP), Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (UNEP, 2011).

United Nations Environment Programme (UNEP), Rotterdam Convention on the Prior Informed Consent (PIC) Procedure for

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Certain Hazardous Chemicals and Pesticides in International Trade (UNEP, 2010).

United Nations Environment Programme (UNEP), Stockholm Convention on Persistent Organic Pollutants (POPs) (UNEP, 2019).

Organisation for the Prohibition of Chemical Weapons (OPCW), Chemical Weapons Convention (OPCW, 2024a, b).

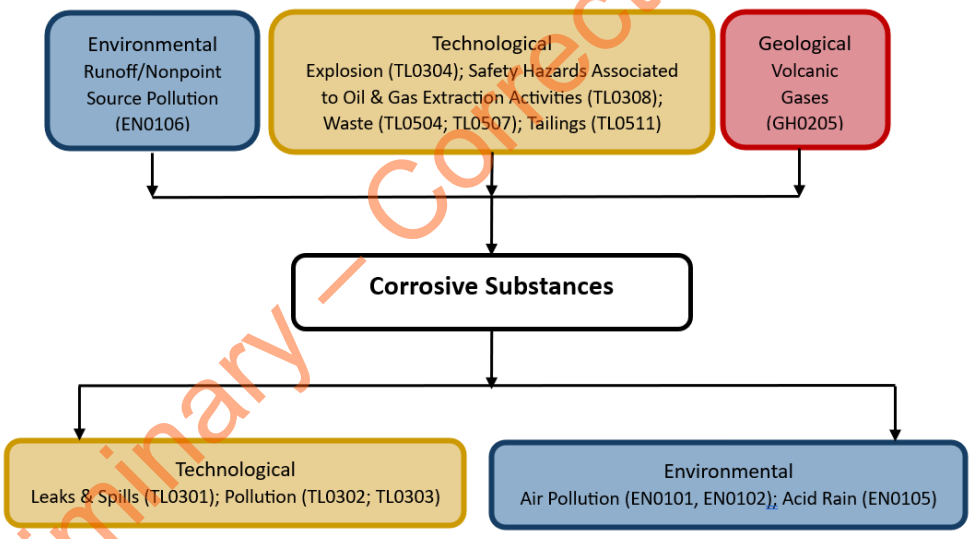
United Nations Environment Programme (UNEP), Montreal Protocol on Substances that Deplete the Ozone Layer (UNEP, 2020)

Examples of hazard drivers, impacts and risk management

Hazard Drivers of corrosive substances, such as strong acids and bases, largely result from their widespread use in industry, as well as in laboratories, for chemical manufacture and synthesis. Industrial processes often use large amounts of acids or bases, such as sulphuric acid, sodium hydroxide and potassium hydroxide, which can lead to hazardous situations. Strong bases are also used in water treatment processes to adjust pH levels and neutralise acidic wastes.

Impacts of strong acids include improper disposal or accidental release, which can lead to soil and water contamination, harming aquatic life and ecosystems, as well as acid rain (HIP MH0033), which is primarily caused by sulphuric and nitric acids - release of sulphur and nitrogen oxides can also lead to air pollution (HIP MH0018; HIP EN0001; HIP EN0002). (EPA, 2024) Acid rain (HIP MH0033) can lead to the corrosion of metals and infrastructure, resulting in leaks, structural failures, and costly repairs. Other impacts include human health risks - coming into contact with strong acids and bases can cause severe chemical burns, skin irritation, eye damage, and respiratory issues. Inhalation of strong acid or strong base vapours can lead to respiratory problems. (NIH, 2022)

Multi-hazard Context: The figure below summarises common interactions between strong acids & strong bases and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring strong acids & strong bases. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Regulatory agencies, health and safety agencies, fire services and manufacturers of chemicals provide material safety data sheets
How is the Hazard Observed/Monitored/Forecast	Sensors, monitoring and alarm systems, preventative maintenance and inspection

Risk Management: strategies include implementing strict safety protocols, providing adequate personal protective equipment (PPE), and conducting thorough employee training on the safe handling and storage of strong acids. (OSHA, 2024) Examples of safety implementations include installing fume hoods, ventilation systems, and acid-resistant materials that can minimise exposure and prevent accidental releases. Ensuring the proper disposal of chemicals through the treatment and disposal methods that minimise environmental impact. Adhering to regulatory requirements and industry standards can also mitigate risks. Further

Preliminary – Corrections Pending

risk management strategies include developing comprehensive emergency response plans, including procedures for spill containment, evacuation, and medical treatment. (NFPA, 2020) In the case of a disaster, using spill kits and flushing the strong acids with plenty of water is advised.

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Coordinating agency or organisation

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0902 / CHEMICAL / Other Chemical Hazards

Ammonium Nitrate

Definition

Ammonium nitrate (NH_4NO_3) is principally used as a high-nitrogen content fertilizer in agricultural applications. It is also a major component of industrial explosives, and similar mixtures have been used as improvised explosive devices. Thousands of people have been killed in accidental ammonium nitrate explosions triggered either by a shock/explosion or by fire spreading into a storage facility. Overuse as a fertilizer can lead to contamination of drinking water.

References

UNECE 2009 Recommendations on the Transport of Dangerous Goods, Model Regulations, Sixteenth edition, United Nations, ISBN` 978-92-1-139136-7 (Recommendations on the Transport of Dangerous Goods, Model Regulations | UNECE)

UK Legislation 2003 (The Ammonium Nitrate Materials (High Nitrogen Content) Safety Regulations 2003 (legislation.gov.uk))

IMO, International Maritime Dangerous Goods Code (IMDG), two volumes. IMO Publications, London (The International Maritime Dangerous Goods (IMDG) Code (imo.org))

Annotations

GHS Classification (UNECE, 2023)

Synonyms

NH_4NO_3, nitrate of ammonia, ammonium saltpetre, Norway saltpetre, AN, ammonium salt of nitric acid

Additional scientific description

Ammonium nitrate is a highly reactive material. Its principal use is as a high-nitrogen content fertiliser, but it is also used in rocket propellants and other explosives. The principal acute hazard is explosive, but overuse in agriculture can lead to contamination of water supplies and contribute to eutrophication. When heated or involved in a fire, ammonium nitrate can decompose, releasing toxic gases including nitrogen oxides and ammonia. It can melt and potentially explode if the molten mass becomes confined. Ammonium nitrate also falls into HSNO Hazard Class 5.1 – oxidising agents. Contact with combustible materials, particularly flammable liquids (HSNO Hazard Class 3 materials) or flammable or reactive solids (HSNO Hazard Class 4) will generate potentially explosive mixtures that may detonate on exposure to even minimal mechanical shocks or mild heating. Mixtures of ammonium nitrate and fuel oil (or other hydrocarbon sources) have been used as improvised explosive devices on both small and large scales (e.g. Oklahoma City bombing). Ammonium nitrate is a strong oxidizer that can accelerate burning when involved in a fire and cause combustible materials (e.g., wood, paper, oil) to ignite, even in the absence of air. The International Labour

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Organisation provides a safety card for the pure compound and notes the shock sensitivity when contaminated with organic material (ILO, no date).

Metrics and numeric limits

Many jurisdictions regulate storage facilities and limit quantities based on conditions due to the potential for accidental detonation. For example, the UK Health and Safety Executive specifies that amounts greater than 150 tons must be notified to the local Fire and Rescue Service (UK HSE, No Date). Detonation resistance tests are sometimes employed (UNECE 2009, UK Legislation 2003)

Key relevant UN convention/multilateral treaty

UNECE Industrial Accidents Convention Industrial accidents | UNECE

Examples of hazard drivers, impacts and risk management

Hazard Drivers Ammonium nitrate is essential and used in large amounts as a fertiliser in maintaining agricultural production to feed increasing populations. In its pure form (>98%), ammonium nitrate is still an explosive, but it is much less sensitive than when mixed with oxidisable fuels. Examples have been reported where bombs or shells have exploded in ammonium nitrate stockpiles and succeeded only in spreading it, but there are also examples where the stockpile has exploded in such circumstances. Ammonium nitrate may be relatively insensitive, but it is also unpredictable. Detonation resistance tests are sometimes employed to assess the explosive tendencies of particular batches of material.

The risk of explosion increases significantly when the material is heated to melting (mp 169ºC), particularly if the liquid is in a confined space. Fire, therefore, presents a particular risk of explosion. Impurities such as chloride salts or heavy metals have been associated with higher risks of explosion, as has low pH (i.e. more acidic conditions) or the presence of high pressures. The sensitivity to detonation also varies with the particle size, with fine powders or porous solids exhibiting higher propensity to explode than larger, more dense particles. The high reactivity of fine powders is likely due to the high surface area (more area at which chemical reaction can occur), while that of the porous solids may be due to both higher surface areas and the ability to absorb contaminants such as those mentioned above. Most ammonium nitrate that is to be used in fertiliser applications is formulated in the denser prill form (small spheres) or granules, but fine powders will inevitably be produced through mechanical action as the material is handled after production.

Impacts: Fires that impact ammonium nitrate transport or storage facilities can trigger explosions (e.g. Oppau, Germany, 1921; Texas City, USA, 1947; Toulouse, France, 2001; Neyshabur, Iran, 2004; Beirut, Lebanon, 2020).

Products from complete reaction of ammonium nitrate during an explosion are dinitrogen (N_2), dioxygen (O_2), and water (H_2O). The high bond energies (946 kJ/mol, 497 kJ/mol, and 926 kJ/mol respectively) of these stable molecules mean that a great deal of energy is released when they are formed, and this contributes to the explosive properties of the compound. The large number of molecules that are produced through the chemical reactions during the explosion contributes to the large forces and blast waves associated with such explosions. The presence of fuel oil or other materials, such as powdered metal, allows further reactions to occur that generate even more energy and more gaseous products (e.g. carbon dioxide, CO_2) that will increase the explosive effect. The explosion may release toxic chemicals (resulting from an incomplete reaction) and spread unreacted ammonium nitrate, contaminating the environment (Rehman 2021).

If it does not explode, ammonium nitrate will decompose on heating to generate toxic nitrogen oxide gases (NOx).

Nitrate run-off from (over-) fertilised pastures can contaminate aquifers and drinking water supplies.

Multi-hazard Context: The figure below summarises common interactions between ammonium nitrate and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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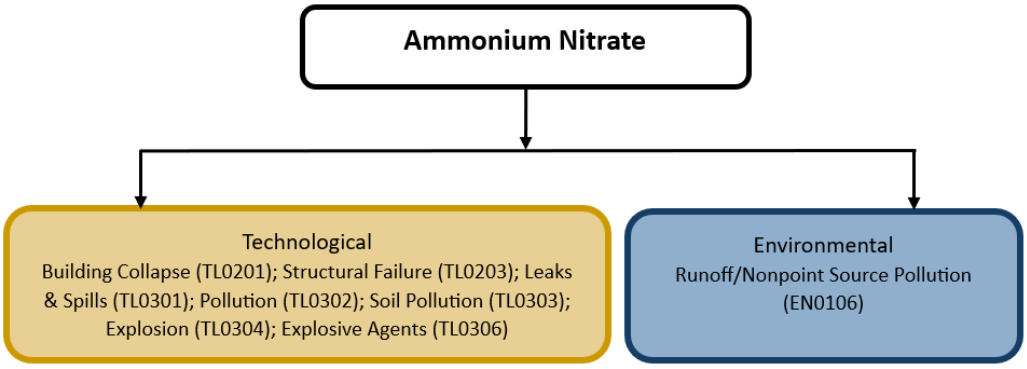

Monitoring: The section and the table below offer an overview of monitoring ammonium nitrate. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	UNECE 2009 Recommendations on the Transport of Dangerous Goods UK Legislation 2003 ILO No Date ICSC 0216 - AMMONIUM NITRATE (ilo.org) IMO, International Maritime Dangerous Goods Code (IMDG)
How is the Hazard Observed/Monitored/Forecast?	Regular inspections as part of risk management may provide some elemen early warning, but the nature of these events makes early warning very dif

Risk Management: The principal hazards of storage of ammonium nitrate are associated with the propensity for explosion, either through direct detonation or detonation as a result of heating and/or melting (possibly as a result of a fire). There are also significant risks associated with contamination and leakage. Contamination with combustible materials through spillage on packaging or other contact can produce materials that are much more sensitive and may detonate on either mild mechanical shocks or minimal heating. Should this occur on even a small scale, it may be sufficient to detonate the surrounding bulk material. Leakage of ammonium nitrate from bags or other containment can result in caking of material on the warehouse floor and an increased risk of contamination with spilled oil (e.g. from forklifts, trucks or other vehicles) and consequent explosion. Sparks from electrical equipment or build-up of static electricity are more likely to initiate an explosion if finely powdered ammonium nitrate is present as a result of leakage from bags. Such powder will almost certainly be present even if the bulk material is made up of prills or granules.

The scale of the hazard will depend on the quantity of the material present, as a large amount of material increases the likelihood of leakage. Furthermore, a large quantity has the potential to generate a very large explosion, whereas a small amount of material will have a correspondingly smaller effect. There are numerous examples of explosions occurring during the transport or storage of ammonium nitrate. In many cases, these have occurred as a result of fires, particularly in enclosed places such as holds of cargo vessels. Some of them have been very large and killed hundreds (e.g. Oppau, Germany, 1921; Texas City, USA, 1947; Toulouse, France, 2001; Neyshabur, Iran, 2004; Beirut, Lebanon, 2020).

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Coordinating agency or organisation

UNECE United Nations Economic Commission for Europe (UNECE)

International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

CH0903 / CHEMICAL / Other Chemical Hazards

Chemical Warfare Agents

Definition

Chemical agents or 'chemical warfare agents' (chemical weapons) are chemicals, including dual-use chemicals, used to cause intentional death or harm through their toxic properties, and are a major public hazard. (OPCW, 2024a, b, c).

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Annotations

GHS Classification (UNECE, 2023)

Synonyms

Nerve agents; blister agents; choking agents; blood agents; riot control agents

Additional scientific description

Chemical warfare agents represent a significant threat due to their potential for mass casualties and long-term environmental and health impacts. Munitions, devices and other equipment specifically designed to deliver toxic chemicals also fall under the definition of chemical weapons. Dual-use chemicals also classify as chemical warfare agents. These are any chemical that has legitimate peaceful uses, but which may also be used to make chemical weapons, for example, thiodiglycol is an ingredient in pen ink that can also be used as a precursor to mustard agents. Equipment in certain chemical production facilities can even be considered dual use in the sense that it may be converted to produce chemical weapons or their precursors. (OPCW, 2024d) The Chemical Weapons Convention (CWC) prohibits the use of toxic chemicals and their precursors and also covers toxins of

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biological origin; it also covers munitions or devices, and equipment directly in connection with these. The relevant toxic chemicals are listed in the Chemical Weapons Convention's Annex on Chemicals (OPCW, 2024b) and, in principle, the understanding and application of a so-called 'General Purpose' Criterion (GPC) and include (OPCW, 2024a):

- Blistering agents: These toxic compounds act via inhalation and contact, affecting the eyes, respiratory tract, and skin, first as an irritant and then as a cell poison. Exposure to blister agents causes large and often life-threatening skin blisters that resemble severe burns and often results in blindness and permanent damage to the respiratory system. Examples include mustard gas (ICSC 0418, 2005).
- Blood agents: These agents inhibit the ability of cells to transfer and use oxygen, effectively causing the body to suffocate. Blood agents generally enter the body through inhalation and are distributed via the blood. Examples include hydrogen cyanide (ICSC 0492, 2018) and cyanogen chloride (ICSC 1053, 1999).
- Choking agents: Inflicting injury mainly on the respiratory tract, choking agents irritate the nose, throat, and especially the lungs. When inhaled, these agents cause alveoli (air sacs in the lungs) to secrete fluid, essentially drowning those affected. Chlorine (ICSC 0126, 2009) and phosgene gas (ICSC 0007, 2013) are examples.
- Nerve agents: Nerve agents block impulses between nerve cells or across synapses and are highly toxic, with rapid effects. They act primarily by absorption through the lungs and skin, inhibiting the action of critical enzymes required for the normal functioning of the nervous system, causing seizures, loss of body control, muscle paralysis (including heart and diaphragm), and ultimately death. Sarin and VX gas are examples.
- Riot control agents: These agents are utilized to temporarily incapacitate a person by irritating the eyes, mouth, throat, lungs and skin, as well as constricting the airways. They are only considered chemical weapons when used in warfare. States can possess these agents for domestic law enforcement purposes, but if they are a member CWC, they must declare which type of agents they have. Examples include tear gas and pepper spray.

Metrics and numeric limits

The Chemical Weapons Convention (OPCW, 2024b, c) categorizes chemical substances into three schedules based on their potential for use in chemical weapons and their toxicity. Schedule 1 chemicals have no or very limited legitimate uses and have strict controls and verification measures. Schedule 2 chemicals have legitimate uses but can also be used as chemical weapons. Schedule 3 chemicals are precursors used in the production of chemical weapons. Parties to the Chemical Warfare Convention must declare any past or current chemical weapons-related activities and facilities, which are verified by the OPCW.

Whilst the Biological Weapons Convention (UNODA, 2021) does not have specific numerical limits, it prohibits the development, production, acquisition, transfer, and stockpiling of biological agents or toxins for hostile purposes.

Key relevant UN convention / multilateral treaty

Organisation for the Prohibition of Chemical Weapons (OPCW), Chemical Weapons Convention. (OPCW, 2024a,b)

United Nations Office for Disarmament Affairs (UNODA), Biological Weapons Convention. (UNODA, 2021)

United Nations Office for Disarmament Affairs (UNODA), UN Security Council Resolution 1540. (UNODA, 2004)

Examples of hazard drivers, impacts and risk management

Hazard Drivers have been wars and civil wars, associated with death, injury and often life-long disabilities (Australia Group, 2021a, b). Other drivers include political and ideological motivations (instilling fear and intimidating adversaries, or to achieve specific political aims), and technological advancements - advances in chemical synthesis, weaponization and delivery systems can lower barriers to acquiring and deploying chemical weapons, making them more accessible to state and non-state actors.

Control measures include import-export control of relevant chemical agents and precursors (Australia Group, 2021a, b). A key factor in ensuring that toxic chemicals and their precursors are not meant to cause death or other harm (i.e., as a 'method of warfare') is the application of the 'General Purpose' Criterion. A given activity or programme may be for 'defensive' (i.e., permitted) or 'offensive' (i.e., prohibited) purposes.

Impacts of chemical weapons include immediate and long-term health effects, and death, resulting in mass casualties, overwhelming healthcare systems, and causing psychological trauma. The deployment of weapons can also lead to environmental contamination, requiring extensive decontamination efforts and long-term ecological consequences. It can also lead to disruption to economic activities and economic losses, hindering recovery efforts. The use of chemical weapons can also provoke international condemnation, trigger diplomatic crises, and lead to military retaliation or sanctions against the responsible parties.

Multi-hazard Context: The figure below summarizes common interactions between chemical warfare agents and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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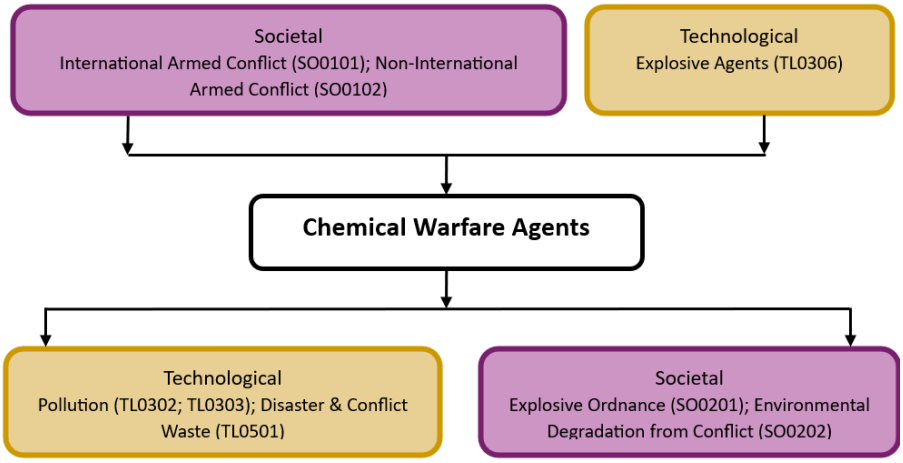

Monitoring: The section and the table below offer an overview of monitoring chemical warfare agents. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Organization for the Prohibition of Chemical Weapons (OPCW); national terrorism agencies
How is the Hazard Observed/Monitored/Forecast?	Sensors; monitoring networks; response protocols

Risk Management strategies include prevention and non-proliferation, by strengthening treaties and verification methods. In addition, an international network of specialized analytical laboratories, able to detect potential chemical warfare agents in the environment and in exposed human bodies, is likely to be of benefit (EU, 2009). New technological approaches are being developed for the detection and monitoring of chemical warfare. Developing and exercising response plans, including medical treatment protocols, decontamination procedures, and public communication strategies, to mitigate the consequences of chemical weapons.

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Coordinating agency or organisation

Organization for the Prohibition of Chemical Weapons (OPCW). International Union of Pure and Applied Chemistry (IUPAC)

Preliminary – Corrections Pending

BIOLOGICAL

Preliminary – Corrections Pending

BI0101 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Airborne Diseases

Definition

Airborne transmission of infectious agents refers to the transmission of disease caused by the dissemination of very small droplets that remain infectious when suspended in air over long distances and time, and potentially cause significant morbidity and mortality (adapted from WHO, 2020).

Reference

WHO, 2020. Transmission of SARS-CoV-2: implications for infection prevention precautions. World Health Organization (WHO). www.who.int/news-room/commentaries/detail/transmission-of-sars-cov-2-implications-for-infection-prevention-precautions Accessed 26 March 2025.

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Annotations

Synonyms

Not identified.

Additional scientific description

The descriptor 'through the air' can be used in an overarching way to characterize an infectious disease where transmission involves the pathogen travelling through or being suspended in the air (WHO, 2024a). Acute respiratory infections (ARIs) are the leading cause of morbidity and mortality from infectious diseases worldwide, particularly affecting the youngest and oldest people in low and middle-income nations (WHO, 2014). These infections, typically caused by viruses, bacteria, fungi, parasites or mixed viral-bacterial infections, can be contagious and spread rapidly. Three main types of organism can cause infectious-related airborne diseases: viruses, bacteria, and fungi. The pathogens that cause respiratory infections include COVID-19, influenza, measles, Middle East respiratory syndrome (MERS), severe acute respiratory syndrome (SARS), and tuberculosis, among others (WHO, 2024a). Some of the common pathogens that may spread via airborne transmission include:

- Anthrax
- Aspergillosis
- Blastomycosis
- Chickenpox
- Adenovirus
- Enteroviruses
- Rotavirus
- Influenza
- Rhinovirus
- Neisseria meningitidis
- Streptococcus pneumoniae
- Legionellosis

- Measles
- Mumps
- Cryptococcosis
- Tuberculosis
- Bordetella pertussis
- Severe acute respiratory syndrome (SARS)
- Middle East respiratory syndrome
- Coronavirus disease 2019 (COVID-19)

Metrics and numeric limits

Metrics and numeric limits are available for some of the individual airborne diseases. The global burden of airborne diseases, particularly respiratory infections, is substantial, with millions of deaths and illnesses annually.

Key relevant UN convention / multilateral treaty

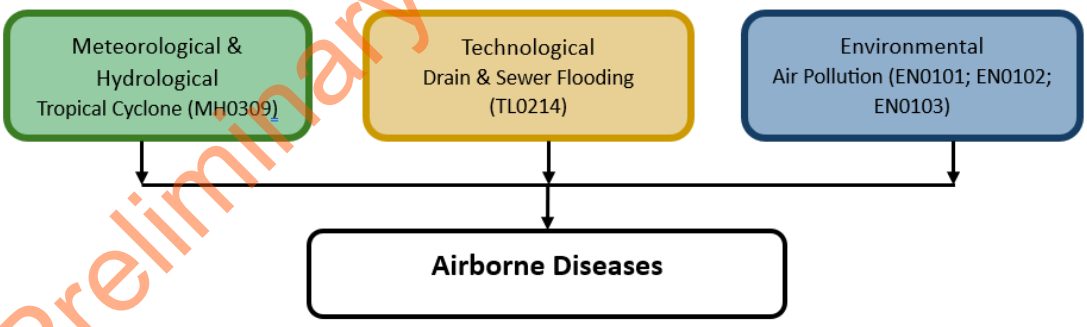
The International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: The microorganisms transmitted by an airborne route may be spread via fine mist, dust, aerosols, or liquids. The aerosolized particles are generated from a source of infection, such as an infected patient or animal. Disease-causing pathogens are organisms that spread from one infected person to another through coughing, talking, and sneezing (WHO, 2014). In addition, aerosols may be generated from biological waste products that accumulate in garbage cans, caves, and dry arid containers. In aerosolization, microorganisms that are less than 100 micrometres in size float in the air (Ather et al., 2023).

Impacts: Acute respiratory diseases are acute upper or lower respiratory tract diseases, frequently infectious in aetiology, that can result in a spectrum of illnesses, ranging from asymptomatic or mild infection to severe or fatal disease. The severity depends on the causative pathogen, and on environmental and host factors (WHO, 2014).

Multi-hazard Context The figure below summarises common interactions between airborne diseases and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Group gatherings in enclosed spaces (e.g., classrooms, conferences) are an important route for the spread of respiratory diseases such as COVID-19. Among the different routes for the disease to spread, indoor activities (e.g., aeroplanes, cruise ships, bars, family gatherings, classrooms) have been characterized as potential super spreading events and such events were the major drivers of the COVID-19 pandemic (Dixit et al., 2023).

Monitoring: Various surveillance systems for individual airborne diseases are available.

For example, the globally coordinated surveillance of influenza, timely sharing of influenza virus data and associated information, and innovative research are key to addressing the problem of influenza. Global influenza surveillance has been conducted through the World Health Organization (WHO) Global Influenza Surveillance and Response System (GISRS) since 1952. GISRS is a system fostering global confidence for over half a century, through effective

Preliminary - Corrections Pending

collaboration and sharing of viruses, data and benefits based on Member States' commitment to a global public health model (WHO, 2024b). The aim of GISRS is to protect people from the threat of influenza by functioning: as a global mechanism of surveillance, preparedness and response for seasonal, pandemic and zoonotic influenza; as a global platform for monitoring influenza epidemiology and disease; and as a global alert for novel influenza viruses and other respiratory pathogens (WHO, 2024b).

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date a).

Risk Management: Airborne diseases pose significant challenges to global health. However, with awareness, education, and the implementation of preventive measures, the spread of these diseases can be mitigated. Vigilance, timely vaccinations, and adherence to hygiene protocols are essential in controlling and preventing the transmission of airborne diseases.

Infection prevention and control (IPC) is a practical, evidence-based approach to preventing patients and health workers from being harmed by avoidable infections (WHO, no date b). Effective IPC requires constant action at all levels of the health system, including policymakers, facility managers, health workers and those who access health services. IPC is unique in the field of patient safety and quality of care, as it is universally relevant to every health worker and patient, at every health care interaction. Defective IPC causes harm and can kill. Without effective IPC it is impossible to achieve quality health care delivery (WHO, no date b).

IPC and water, sanitation and hygiene (WASH) are central to public health emergencies, including outbreak response and containment. IPC also constitutes the foundations of safe essential health services and resilient communities and health systems, ensuring quality care, and protecting against health care-associated infections and anti-microbial resistance. The success of ensuring IPC measures are implemented for outbreak response, in health facilities and communities, is dependent upon maintaining IPC operational readiness to rapidly respond to cases and putting in place at least the IPC minimum requirements at the national and health care facility levels as soon as possible. Over the past decade, the landscape of respiratory viruses has evolved significantly, exemplified by the profound impact of the recent COVID-19 pandemic (WHO, 2024c).

Infection prevention and control (IPC) is a scientific approach and set of practices designed to prevent harm caused by infection to patients and health workers. Use of appropriate IPC measures is essential for the protection of patients, healthcare workers, and the wider community. Correct implementation of the necessary IPC measures is an essential aspect of safe and successful management of airborne diseases (WHO, no date b). IPC affects all aspects of health care, including hand hygiene, surgical site infections, injection safety, antimicrobial resistance and how hospitals operate during and outside of emergencies. Programmes to support IPC are particularly important in low- and middle-income countries, where health care delivery and medical hygiene standards may be negatively affected by secondary infections. Much of the work done on IPC is hidden, as by its nature it prevents issues rather than treating them after the fact (WHO, no date b).

The first WHO Global Patient Challenge laid the foundations for the IPC Global Unit, which works to support country capacity-building for IPC action. Through this programme, WHO provides technical assistance for developing local IPC policies and guidelines, performs in-country assessments, convenes meetings focused on guideline development and provides ongoing support for health care providers (WHO, 2005).

WHO also makes a global annual call to action for health workers through the SAVE LIVES: Clean Your Hands campaign held each May (WHO, no date c). This campaign seeks to educate health workers and patients on the importance of effective hand washing, the need for which has become more acute with the COVID-19 pandemic (WHO, no date c).

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Vaccines are available for various airborne diseases, including measles and influenza, which reduce the risk of getting diseases by working with the body's natural defences to build protection. The Global Vaccine Action Plan 2011-2020, endorsed by the 194 Member States of the World Health Assembly in May 2012, is a framework to prevent millions of deaths by 2020 through more equitable access to existing vaccines for people in all communities (WHO, 2013). The Global Vaccine Action Plan was the product of the Decade of Vaccines Collaboration, an unprecedented effort that brought together development, health and immunisation experts and stakeholders (WHO, 2013). The SAGE Global Vaccine Action Plan (GVAP) 2011-2020 review and lessons learned report, provides an overall assessment of the plan's successes and challenges. It also proposed 15 recommendations for the development, content and implementation of the next decade's global immunization strategy (WHO, 2020).

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Preliminary – Corrections Pending

Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0102 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Bloodborne Viruses

Definition

Bloodborne viruses are viruses transmitted by direct contact with infected blood or other body fluids (adapted from WHO, 2023).

Reference

WHO, 2023. Blood safety and availability. World Health Organization (WHO) https://www.who.int/news-room/fact-sheets/detail/blood-safety-and-availability Accessed 1 April 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Blood-borne viruses; Blood Borne viruses; BBV.

Additional scientific description

Blood-borne viruses are viruses that some people carry in their blood, and which can be spread from one person to another. Those infected with a blood-borne virus may show little or no symptoms of serious disease, while other infected people may be severely ill. An infected person can transmit (spread) blood-borne viruses from one person to another by various routes and over a prolonged time period (HSE, no date a). Bloodborne pathogens include the human immunodeficiency virus (HIV), hepatitis B virus (HBV), and hepatitis C virus (HCV) (CDC, 2024).

Metrics and numeric limits

Although global data for all exposures is not available, according to the World Health Organization (WHO), out of the 35 million Health Care Workers (HCWs) worldwide, 3 million experience percutaneous exposure to various bloodborne pathogens, with 2 million to HBV, 0.9 million to HCV, and 170,000 to HIV. Over 90% of these infections occur in developing countries (WHO, 2003).

Key relevant UN convention/multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Blood-borne viruses (BBVs) are transmitted by blood, or other body fluids containing the virus. This happens when the blood or fluids enter the body of a susceptible person. The rate of viral transmission varies depending on how the person has been exposed to the virus (the route of transmission), the type of virus, how much of the virus the carrier has in their body and the immune status of the exposed person (HSE, no date b).

The more common routes of transmission include sexual intercourse (common for HBV, HIV; inefficient for HCV); sharing injecting equipment; skin puncture by blood-contaminated sharp objects (e.g needles, instruments or glass); and childbirth (ie the mother infects the child either before or during birth, or through breast-feeding) (HSE, no date b).

Less common routes of transmission are: contamination of open wounds (e.g blood injuries during sporting activities); contamination of skin lesions (e.g eczema); splashing of the mucous membranes of the eye, nose or mouth; and human bites when blood is drawn (this may be more of a problem in certain occupations, e.g prison and police service, where front line workers may be exposed to violent behaviour) (HSE, no date b).

There is also a risk of acquiring a blood-borne virus infection via blood transfusion. For example, in the UK, all blood donations are screened for HBV, HCV and HIV, meaning the risk is remote (HSE, no date b).

Health care workers are at risk of infection with blood-borne pathogens because of occupational exposure to blood and body fluids. Most exposures are caused by 'sharps' – contaminated sharp objects, such as syringe needles, scalpels and broken

glass. Needlestick injuries contribute to 39%, 37% and 4.4% of hepatitis C, hepatitis B and HIV infections respectively (Prüss-Üstün et al., 2005).

Impacts: Bloodborne pathogens include the human immunodeficiency virus (HIV), hepatitis B virus (HBV), and hepatitis C virus (HCV) (CDC, 2024). These infections are, for the most part, preventable, as shown by the low rates achieved in certain countries that have engaged in serious prevention efforts, including training of health care workers, HBV immunisation, post-exposure prophylaxis and improved waste management. In addition to the disease, the burden caused to health care workers, and the functioning of the health care system may be reduced because of impaired working capacity, especially in developing countries where the proportion of health care workers in the population is already small compared with that in developed countries (WHO, 2005).

Multi-hazard Context: Not Applicable

Monitoring: WHO recommends that all blood donations should be screened for infections prior to use. Screening for HIV, hepatitis B, hepatitis C, and syphilis should be mandatory. Blood screening should be performed according to quality system requirements. Of reporting countries, 10 are not able to screen all donated blood for one or more of the above infections (WHO, 2023). 99.8% of the donations in high-income countries and 99.9% in upper-middle-income countries are screened following basic quality procedures, as compared to 83% in lower-middle-income countries and 76 % in low-income countries. The prevalence of transfusion-transmissible infections in blood donations in high-income countries is considerably lower than in low- and middle-income countries (WHO, 2023).

Risk Management: Bloodborne virus transmission has been reported from patient to patient, patient to health care workers, and rarely, from health care worker to patient (Hu et al., 1991). For health care and other emergency workers, standard precautions are meant to reduce the risk of transmission of blood-borne and other pathogens from both recognised and unrecognised sources (WHO, 2007).

Standard precautions are the basic level of infection control precautions which are to be used, as a minimum, in the care of all patients. Hand hygiene is a major component of standard precautions and one of the most effective methods to prevent transmission of pathogens associated with health care. In addition to hand hygiene, the use of personal protective equipment should be guided by risk assessment and the extent of contact anticipated with blood and body fluids, or pathogens (WHO, 2007).

In addition to practices carried out by health workers when providing care, all individuals (including patients and visitors) should comply with infection control practices in health-care settings. The control of spread of pathogens from the source is key to avoiding transmission. Among source control measures, respiratory hygiene/cough etiquette is now considered as part of standard precautions, which include sterilization and medical device decontamination, safe handling of linen and laundry, use of personal protective clothing and management of health care waste (WHO, 2007; 2019).

Worldwide escalation of the use of standard precautions would reduce unnecessary risks associated with health care. Promotion of an institutional safety climate helps to improve conformity with recommended measures and thus subsequent risk reduction. Provision of adequate staff and supplies, together with leadership and education of health workers, patients, and visitors, is critical for an enhanced safety climate in health-care settings (WHO, 2007).

Of the 118.5 million blood donations collected globally, 40% of these are collected in high-income countries, home to 16% of the world's population. In low-income countries, up to 54 % of blood transfusions are given to children under 5 years of age, whereas in high-income countries, the most frequently transfused patient group is over 60 years of age, accounting for up to 76% of all transfusions (WHO, 2023).

The risk of transmission of serious infections, including HIV and hepatitis, through unsafe blood and chronic blood shortages brought global attention to the importance of blood safety and availability (WHO, 2023). With the goal of ensuring universal access to safe blood and blood products, WHO has been at the forefront of improving blood safety and availability, and recommends the following integrated strategy for blood safety and availability:

- Establishment of a national blood system with well-organized and coordinated blood transfusion services, effective evidence-based and ethical national blood policies, and legislation and regulation, that can provide sufficient and timely supplies of safe blood and blood products to meet the transfusion needs of all patients.
- Collection of blood, plasma and other blood components from low-risk, regular, voluntary unpaid donors through the strengthening of donation systems, and effective donor management, including care and counselling.
- Quality-assured screening of all donated blood for transfusion-transmissible infections, including HIV, hepatitis B, hepatitis C and syphilis, confirmatory testing of the results of all donors screen-reactive for infection markers, blood grouping and compatibility testing, and systems for processing blood into blood products (blood components for transfusion and plasma derived-medicinal products), as appropriate, to meet health care needs.
- Rational use of blood and blood products to reduce unnecessary transfusions and minimize the risks associated with transfusion, the use of alternatives to transfusion where possible, and safe and good clinical transfusion practices, including patient blood management.

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- Stepwise implementation of effective quality systems, including quality management, standards, good manufacturing practices, documentation, training of all staff, and quality assessment (WHO, 2023).

WHO supports countries in developing national blood systems to ensure timely access to safe and sufficient supplies of blood and blood products and good transfusion practices to meet patient needs. WHO provides policy guidance and technical assistance to countries to ensure universal access to safe blood and blood products, and work towards self-sufficiency in safe blood and blood products based on voluntary unpaid blood donation to achieve universal health coverage (WHO, 2023).

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0103 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Diarrhoeal Diseases (Human)

Definition

Diarrhoeal diseases are infectious diseases, contaminants and other causes of diarrhoea. Diarrhoea is defined as the passage of three or more loose or liquid stools per day, or more frequently than is normal for the individual. Diarrhoeal disease is the third leading cause of death in children 1-59 months of age. It is both preventable and treatable. (WHO, 2024a).

Reference

WHO, 2024a. Diarrhoea. World Health Organization (WHO). https://www.who.int/news-room/fact-sheets/detail/diarrhoeal-disease Accessed 26 March 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Gastroenteritis, dysentery. Frequent, watery stools. Loose stools.

Additional scientific description

Diarrhoeal disease is the third leading cause of death in children under 5 years old and is responsible for killing around 443,832 children every year. Diarrhoea can last several days and can leave the body without the water and salts that are necessary for survival. In the past, for most people, severe dehydration and fluid loss were the main causes of diarrhoea-associated deaths. Now, other causes such as septic bacterial infections are likely to account for an increasing proportion of all diarrhoea-associated deaths. Children who are malnourished or have impaired immunity, as well as people living with HIV, are most at risk of life-threatening diarrhoea (WHO, 2024).

Diarrhoea is defined as the passage of 3 or more loose or liquid stools per day (or more frequent passage than is normal for the individual). Frequent passing of formed stools is not diarrhoea, nor is the passing of loose, pasty stools by breastfed babies.

Diarrhoea is usually a symptom of an infection in the intestinal tract, which can be caused by a variety of bacterial, viral and parasitic organisms. Infection is spread through contaminated food or drinking water, or from person-to-person as a result of poor hygiene.

Interventions to prevent diarrhoea, including safe drinking water, use of improved sanitation and hand washing with soap, can reduce disease risk. Diarrhoea should be treated with oral rehydration solution (ORS), a solution of clean water, sugar and salt. In addition, a 10-14-day supplemental treatment course of dispersible zinc tablets shortens diarrhoea duration and improves outcomes.

There are 3 clinical types of diarrhoea:

- acute watery diarrhoea – lasts several hours or days and includes cholera
- acute bloody diarrhoea – also called dysentery
- persistent diarrhoea – lasts 14 days or longer.

Metrics and numeric limits

Diarrhoeal disease is a leading cause of child mortality and morbidity in the world and mostly results from contaminated food and water sources. Worldwide, 780 million individuals lack access to improved drinking water and 2.5 billion lack improved sanitation. Diarrhoea due to infection is widespread throughout developing countries (WHO, 2024a).

In low-income countries, children under 3 years old experience on average three episodes of diarrhoea every year. Each episode

deprives the child of the nutrition necessary for growth. As a result, diarrhoea is a major cause of malnutrition, and malnourished children are more likely to fall ill from diarrhoea (WHO, 2024a).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers include infection, underlying malnutrition, water contamination and other causes such as poor personal hygiene (WHO, 2024). In summary, these are described below:

- ***Infection***: Diarrhoea is a symptom of infections caused by a host of bacterial, viral and parasitic organisms, most of which are spread by faeces-contaminated water. Infection is more common when there is a shortage of adequate sanitation and hygiene and safe water for drinking, cooking and cleaning. Among children under 5 years of age, the most common viral pathogens are rotavirus, norovirus, adenovirus and astrovirus. Bacterial pathogens include *Escherichia coli, Salmonella spp., Shigella spp., and Campylobacter spp.*, while parasitic pathogens include *Cryptosporidium*, *Giardia*, and *Entamoeba spp*. Rotavirus and *E. coli* are the most common pathogens among children across all age groups, while parasitic pathogens are prevalent in children aged 3-5 years. Bacterial pathogens, including *E. coli*, *Salmonella*, and *Shigella*, were common in the children aged 6 to 10-year age group, as were rotavirus, norovirus, and sapovirus. Location-specific etiologic patterns also need to be considered (WHO, 2024a).
- ***Malnutrition***: Children who die from diarrhoea often suffer from underlying malnutrition, which makes them more vulnerable to diarrhoea. Each diarrhoeal episode, in turn, makes their malnutrition even worse. Diarrhoea is a leading cause of malnutrition in children under 5 years old (WHO, 2024a).
- ***Source***: Water contaminated with human faeces, for example from sewage, septic tanks and latrines, is of particular concern. Animal faeces also contain microorganisms that can cause diarrhoea (WHO, 2024a).
- ***Other causes***: Diarrhoeal disease can also spread from person-to-person, aggravated by poor personal hygiene. Food is another major cause of diarrhoea when it is prepared or stored in unhygienic conditions. Unsafe domestic water storage and handling is also an important risk factor. Fish and seafood from polluted water may also contribute to the disease (WHO, 2024a).

Impacts: Globally, there are nearly 1.7 billion cases of childhood diarrhoeal disease every year (WHO, 2024a). Diarrhoea is a leading cause of malnutrition in children under 5 years old (WHO, 2024a).

The most severe threat posed by diarrhoea is dehydration. During a diarrhoeal episode, water and electrolytes (sodium, chloride, potassium and bicarbonate) are lost through liquid stools, vomit, sweat, urine and breathing (WHO, 2024a). Dehydration occurs when these losses are not replaced.

WHO (2024a) describes the degree of dehydration as rated on a scale of 3.

- severe dehydration (at least two of the following signs):
  - lethargy/unconsciousness
  - sunken eyes
  - unable to drink or drink poorly
  - skin pinch goes back very slowly (≥2 seconds)
- some dehydration (two or more of the following signs):
  - restlessness, irritability
  - sunken eyes
  - drinks eagerly, thirsty
- no dehydration (not enough signs to classify as some or severe dehydration)

Multi-hazard Context The figure below summarises common interactions between diarrhoeal diseases and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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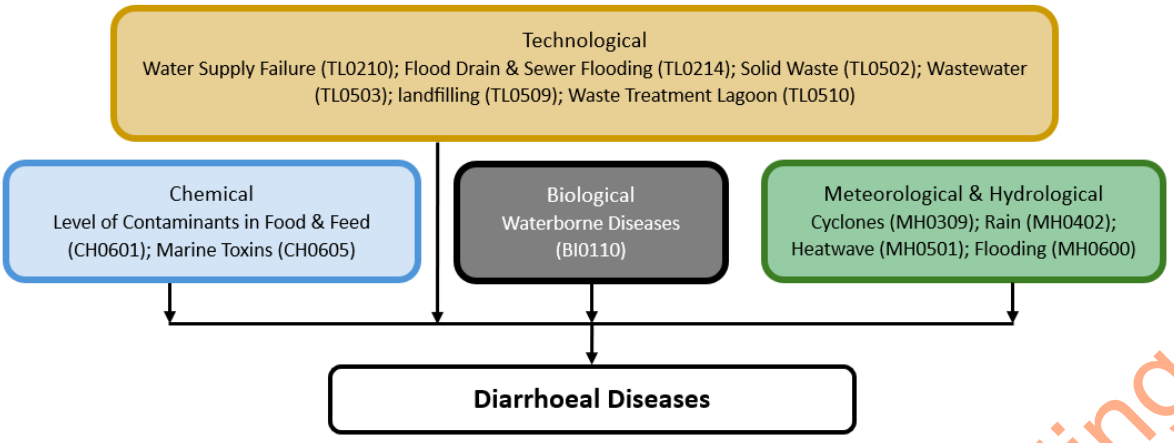

Monitoring: WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

Many individual diarrhoeal diseases have monitoring systems, For example, cholera surveillance should be part of an integrated disease surveillance system. This includes timely reporting, data analysis, interpretation and sharing of information from local to global levels. Rapid diagnostic tests (RDTs) are useful for early detection of probable cholera outbreaks, but confirmation requires laboratory testing by culture, seroagglutination or polymerase chain reaction (PCR) (WHO, 2024b). Countries at risk or affected by cholera should strengthen their surveillance systems according to the revised Global Taskforce on Cholera Control (GTFCC) recommendations to quickly detect and respond to outbreaks (GTFCC, 2025).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date).

Risk Management WHO (2024a) has identified key measures to treat diarrhoea as follows:

- Rehydration with oral rehydration salts (ORS) solution. ORS is a mixture of clean water, salt and sugar. It costs a few cents per treatment. ORS is absorbed in the small intestine and replaces the water and electrolytes lost in the faeces.
- Zinc supplements reduce the duration of a diarrhoea episode by 25% and are associated with a 30% reduction in stool volume.
- Rehydration with intravenous fluids in case of severe dehydration or shock.
- Nutrient-rich foods. The vicious circle of malnutrition and diarrhoea can be broken by continuing to give nutrient-rich foods – including breast milk – during an episode, and by giving a nutritious diet – including exclusive breastfeeding for the first 6 months of life – to children when they are well.

Consulting a health professional, in particular for the management of persistent diarrhoea, when there is blood in the stool, or if there are signs of dehydration, is recommended (WHO, 2024a).

WHO (2024a) recommends the following key measures to prevent diarrhoea to include:

- access to safe drinking water
- use of improved sanitation
- hand washing with soap
- exclusive breastfeeding for the first 6 months of life
- good personal and food hygiene
- health education about how infections spread
- rotavirus vaccination.

In addition, WHO works with Member States and other partners to:

- promote national policies and investments that support case management of diarrhoea and its complications as well as increasing access to safe drinking water and sanitation in developing countries;
- conduct research to develop and test new diarrhoea prevention and control strategies in this area;

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- build capacity in implementing preventive interventions, including sanitation, source water improvements, and household water treatment and safe storage;
- develop new health interventions, such as the rotavirus immunization; and
- help to train health workers, especially at the community level (WHO, 2024a).

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0104 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Foodborne Diseases

Definition

Foodborne diseases are caused by contamination of food and occur at any stage of the food production, delivery and consumption chain. They can result from several forms of environmental contamination including pollution in water, soil or air, as well as unsafe food storage and processing. Foodborne diseases encompass a wide range of illnesses from diarrhoea to cancers (WHO, no date a).

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Reference

WHO, no date a. Foodborne Diseases. World Health Organization (WHO). www.who.int/health-topics/foodborne-diseases#tab=tab_1 Accessed 16 February 2025

Annotations

Synonyms

Foodborne illnesses. Food poisoning.

Additional scientific description

Over 200 diseases are caused by ingestion of food that is contaminated with bacteria, viruses, parasites or chemical substances such as heavy metals. This growing public health concern causes considerable socioeconomic impacts through strains on healthcare systems, lost productivity, and harm to tourism and trade. These diseases contribute significantly to the global burden of disease and mortality (WHO, no date a).

The contamination of food may occur at any stage of the food production, delivery and consumption chain. Foodborne diseases can result from several forms of environmental contamination, including pollution in water, soil or air, as well as unsafe food storage and processing (WHO, no date a).

Foodborne disease hazards include (but are not limited to) pathogenic bacteria, viruses, algae, protozoa, fungi, parasites, prions, toxins and other harmful metabolites of microbial origin, as well as chemicals and radioactive materials.

Foodborne illnesses are usually infectious or toxic in nature and caused by bacteria, viruses, parasites or chemical substances entering the body through contaminated food. Chemical contamination can lead to acute poisoning or long-term diseases, such as cancer (WHO, 2024). Many foodborne diseases may lead to long-lasting disability and death. Some examples of food hazards are listed below.

- ***Bacteria:***
  - Salmonella, Campylobacter and enterohaemorrhagic Escherichia coli are some of the most common foodborne pathogens that affect millions of people annually, sometimes with severe and fatal outcomes. Symptoms can include fever, headache, nausea, vomiting, abdominal pain and diarrhoea. Foods more frequently involved in outbreaks of salmonellosis include eggs, poultry and other products of animal origin. Foodborne cases due to Campylobacter are mainly caused by raw milk, raw or undercooked poultry and drinking water. Enterohaemorrhagic Escherichia coli is often associated with unpasteurized milk, undercooked meat and contaminated fresh fruits and vegetables (WHO, 2024).
  - Listeria infections can lead to miscarriage in pregnant women or death of newborn babies. Although disease occurrence is relatively low, Listeria's severe and sometimes fatal health consequences, particularly among infants, children and the

elderly, count them among the most serious foodborne infections. Listeria is found in unpasteurised dairy products and various ready-to-eat foods and can grow at refrigeration temperatures (WHO, 2024).

- Vibrio cholerae can infect people through contaminated water or food. Symptoms may include abdominal pain, vomiting and profuse watery diarrhoea, which quickly lead to severe dehydration and possibly death. Raw vegetables and various types of raw or undercooked seafood have been implicated in cholera outbreaks (WHO, 2024).
- Antimicrobials, such as antibiotics, are essential to treat infections caused by bacteria, including foodborne pathogens. However, their overuse and misuse in veterinary and human medicine has been linked to the emergence and spread of resistant bacteria, rendering the treatment of infectious diseases ineffective in animals and humans (WHO, 2024).

- ***Viruses:*** Some viruses can be transmitted by food consumption. Norovirus is a common cause of foodborne infections that is characterized by nausea, explosive vomiting, watery diarrhoea and abdominal pain. Hepatitis A virus can also be transmitted by food and can cause long-lasting liver disease and typically spreads through raw or undercooked seafood or contaminated raw produce (WHO, 2024).
- ***Parasites:*** Some parasites, such as fish-borne trematodes, are only transmitted through food. Others, for example, tapeworms like *Echinococcus spp*, or *Taenia spp*, may infect people through food or direct contact with animals. Other parasites, such as Ascaris, Cryptosporidium, Entamoeba histolytica or Giardia, enter the food chain via water or soil and can contaminate fresh produce (WHO, 2024).
- ***Prions:*** Prions, infectious agents composed of protein, are unique in that they are associated with specific forms of neurodegenerative disease. Bovine spongiform encephalopathy (BSE, or so-called mad cow disease) is a prion disease in cattle, associated with the variant Creutzfeldt-Jakob disease (vCJD) in humans. Consuming meat products containing specified risk material, such as brain tissue, is the most likely route of transmission of the prion agent to humans (WHO, 2024).
- ***Chemicals*** - of most concern for health are naturally occurring toxins and environmental pollutants.
  - *Naturally occurring toxins* include mycotoxins, marine biotoxins, cyanogenic glycosides and toxins occurring in poisonous mushrooms. Staple foods like corn or cereals can contain high levels of mycotoxins, such as aflatoxin and ochratoxin, produced by mould on grain. Long-term exposure can affect the immune system and normal development, or cause cancer (WHO, 2024).
  - *Persistent organic pollutants (POPs)* are compounds that accumulate in the environment and the human body. Known examples are dioxins and polychlorinated biphenyls (PCBs), which are unwanted by-products of industrial processes and waste incineration. They are found worldwide in the environment and accumulate in animal food chains. Dioxins are highly toxic and can cause reproductive and developmental problems, damage the immune system, interfere with hormones and cause cancer (WHO, 2024).
  - *Heavy metals* such as lead, cadmium and mercury cause neurological and kidney damage. Contamination by heavy metals in food occurs mainly through pollution of water and soil (WHO, 2024).
- ***Other hazards*** in food can include radioactive nucleotides that can be discharged into the environment from industries and from civil or military nuclear operations, food allergens, residues of drugs and other contaminants incorporated in the food during the process (WHO, 2024).

Metrics and numeric limits

The World Health Organization (WHO) reports that each year worldwide, unsafe food causes 600 million cases of foodborne diseases and 420,000 deaths. 30% of foodborne deaths occur among children under 5 years of age. The WHO estimated that 33 million years of healthy lives are lost due to eating unsafe food globally each year, and that this number is likely to be an underestimate (WHO, 2021 a).

Key relevant UN convention / multilateral treaty

The Joint Food and Agriculture Organization of the United Nations (FAO) and WHO Food Standards Program (Codex Alimentarius Commission) for the establishment of food safety standards, such as maximum levels for food additives (quantitative levels above which there is a risk for consumers' health) (FAO and WHO, no date).

The WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) (WTO, no date).

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Access to sufficient amounts of safe and nutritious food is key to sustaining life and promoting good health. Unsafe food containing harmful bacteria, viruses, parasites or chemical substances causes more than 200 diseases, ranging from diarrhoea to cancers. It also creates a vicious cycle of disease and malnutrition, particularly affecting infants, young children, the

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elderly and the sick. Good collaboration between governments, food producers, and consumers is needed to help ensure food safety and stronger food systems (WHO, 2024).

Impacts: Every year, nearly one in 10 people around the world fall ill after eating contaminated food, leading to over 420,000 deaths. Children are disproportionately affected, with 125,000 deaths every year in people under 5 years of age. The majority of these cases are caused by diarrhoeal diseases. Other serious consequences of foodborne diseases include kidney and liver failure, brain and neural disorders, reactive arthritis and cancer (WHO, no date a).

Multi-hazard Context: Foodborne diseases are closely linked to poverty in low- and middle-income countries but are a growing public health issue around the world. Increasing international trade and longer, more complex food chains increase the risk of food contamination and the transport of infected food products across national borders. Growing cities, climate change, migration and growing international travel compound these issues and expose people to new hazards (WHO, no date a).

Monitoring: WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021 b).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date b).

Risk Management: WHO works to assist Member States in building capacity to prevent, detect and manage foodborne risks. Foodborne diseases are reflected in several targets of United Nations Sustainable Developmental Goal 3 and are a priority area within WHO's work Activities include research and independent scientific assessments of food-related hazards, foodborne disease awareness programmes, and helping to promote food safety through national healthcare programmes (WHO, no date a). WHO aims to strengthen national food control systems to facilitate global prevention, detection and response to public health threats associated with unsafe food (WHO, 2025). To do this, WHO supports Member States by:

- facilitating the implementation of the WHO Global Strategy for Food Safety (2022-2030) to support Member States in strengthening their national food control systems and reducing the burden of foodborne diseases through the activities of the WHO Alliance for Food Safety tacking the One Health approach (WHO, 2022);
- providing independent scientific assessments on microbiological and chemical hazards that form the basis for international food standards, guidelines, and recommendations, known as the Codex Alimentarius (FAO & WHO, no date);
- assessing the performance of national food control systems throughout the entire food chain, identifying priority areas for further development, and measuring and evaluating progress over time through the FAO/WHO food control system assessment tool (WHO and FAO, 2021);
- assessing the safety of new technologies used in food production, such as genetic modification, cultivated food products and nanotechnology;
- helping implement adequate infrastructure to manage food safety risks and respond to food safety emergencies through the International Food Safety Authorities Network (INFOSAN) (WHO, no date c);
- promoting safe food handling through systematic disease prevention and awareness programmes, through the WHO Five Keys to Safer Food message and training materials (WHO, 2006);
- advocating for food safety as an important component of health security and for integrating food safety into national policies and programmes in line with the International Health Regulations (IHR 2005) (WHO, 2016);
- strengthening surveillance of and response to foodborne diseases globally by supporting countries to improve their current foodborne disease surveillance and response activities (WHO, 2017) (including through the use of Whole Genome Sequencing (WGS) (WHO, 2023)) and integrate them into existing national surveillance and response systems required by the IHR 2005; and
- monitoring regularly the global burden of foodborne diseases at national, regional and international levels (WHO, no date d), and supporting countries to estimate the national burden of foodborne diseases (WHO, 2021 a) or utilize existing burden estimates to inform food safety policies.

WHO works closely with the Food and Agriculture Organization (FAO), the World Organization for Animal Health (WOAH), the UN Environment Programme (UNEP) and other international organizations to ensure food safety along the entire food chain from production to consumption, in line with the One health joint plan of action (2022–2026): working together for the health of humans, animals, plants and the environment (FAO et al., 2022).

Preliminary – Corrections Pending

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Coordinating agency or organisation

World Health Organization, Food and Agriculture Organization of the United Nations, Joint Food and Agriculture Organization of the United Nations/ World Health Organization Food Standards Program (Codex Alimentarius Commission) for the establishment of food safety standards e.g. MLs for food additives (quantitative levels above which there is a risk for consumer's health). Scientific advice on microbiological hazards in foods is provided by the Joint Food and Agriculture Organization of the United Nations/ World Health Organization Expert Meetings on Microbiological Risk Assessment (JEMRA).

Preliminary – Corrections Pending

BI0105 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Neglected Tropical Diseases (Human)

Definition

Neglected tropical diseases (NTDs) are a diverse group of conditions caused by a variety of pathogens (including viruses, bacteria, parasites, fungi and toxins) and associated with devastating health, social and economic consequences. NTDs are mainly prevalent among impoverished communities in tropical areas, although some have a much larger geographical distribution. (WHO, no date a).

Reference

WHO, no date. Neglected Tropical Diseases. World Health Organization (WHO). Overview. https://www.who.int/health-topics/neglected-tropical-diseases#tab=tab_1 Accessed 18 February 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Not applicable.

Additional scientific description

Neglected tropical diseases (NTDs) are a diverse group of conditions caused by a variety of pathogens (including viruses, bacteria, parasites, fungi and toxins) and associated with devastating health, social and economic consequences. NTDs are mainly prevalent among impoverished communities in tropical areas, although some have a much larger geographical distribution. It is estimated that NTDs affect more than 1 billion people, while the number of people requiring NTD interventions (both preventive and curative) is 1.6 billion (WHO, no date a).

The epidemiology of NTDs is complex and often related to environmental conditions. Many of them are vector-borne, have animal reservoirs and are associated with complex life cycles. All these factors make their public-health control challenging. (WHO, no date a).

In addition to significant mortality and morbidity - approximately 200,000 deaths and 19 million disability-adjusted life years (DALYs) lost annually, NTDs cost developing communities the equivalent of billions of United States dollars each year in direct health costs, loss of productivity and reduced socioeconomic and educational attainment. They are also responsible for other consequences such as disability, stigmatization, social exclusion and discrimination and place considerable financial strain on patients and their families.

In spite of this, NTDs have historically ranked very low and almost absent from the global health policy agenda - only to gain recognition in 2015 with the Sustainable Development Goals (SDG target 3.3). SDG3 can therefore be achieved only if the NTD goals are met but, because interventions to tackle NTDs are widely cross-sectoral, increasing their global prioritization can in fact catalyse progress to achieve all SDGs (WHO no date b). As a result, neglected tropical diseases trap the poor in a cycle of poverty and disease (WHO, no date).

At present, the World Health Organization (WHO) categorizes the following group of conditions as NTDs which are caused by a variety of pathogens, (including Viruses, Bacteria, parasites, fungi and toxins) (WHO, no date a)as including:

- Buruli ulcer (Mycobacterium ulcerans infection)
- Chagas disease (also known as American trypanosomiasis)
- Chromoblastomycosis
- Chikungunya (BI0203)

- Dengue and severe dengue (BI0207)
- Dracunculiasis (Guinea-worm disease)
- Echinococcosis
- Foodborne trematode infections
- Trypanosomiasis, human African (sleeping sickness) (BI0238)
- Leishmaniasis
- Leprosy (BI0216)
- Lymphatic filariasis
- Mycetoma
- Noma
- Onchocerciasis
- Podoconiosis (non-filarial lymphoedema)
- Rabies (BI0232)
- Scabies
- Schistosomiasis
- Snakebite envenoming (BI0605)
- Soil-transmitted helminth infections
- Sporotrichosis
- Taeniasis/cysticercosis
- Trachoma
- Tungiasis
- Yaws

Metrics and numeric limits

WHO estimates that over 1.6 billion of the world's population should be targeted by prevention and treatment activities for at least one of these diseases, every year. In addition to significant mortality and morbidity - approximately 200,000 deaths and 19 million disability-adjusted life years (DALYs) are lost annually (WHO, no date b).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Neglected tropical diseases (NTDs) are a diverse group of conditions caused by a variety of pathogens (including viruses, bacteria, parasites, fungi and toxins) and associated with devastating health, social and economic consequences. NTDs are mainly prevalent among impoverished communities in tropical areas, although some have a much larger geographical distribution. It is estimated that NTDs affect more than 1 billion people, while the number of people requiring NTD interventions (both preventive and curative) is 1.6 billion (WHO, no date a).

Impacts: NTDs cause significant mortality and morbidity cost developing communities the equivalent of billions of United States dollars each year in direct health costs, loss of productivity and reduced socioeconomic and educational attainment. They are also responsible for other consequences such as disability, stigmatization, social exclusion and discrimination and place considerable financial strain on patients and their families (WHO, no date b).

Multi-hazard Context: The epidemiology of NTDs is complex and often related to environmental conditions. Many of them are vector-borne, have animal reservoirs and are associated with complex life cycles. All these factors make their public-health control challenging (WHO, no date a).

Monitoring: WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance

Preliminary – Corrections Pending

system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date d).

Risk Management: WHO's action to control, prevent, eliminate and eradicate NTDs is guided by the NTD road map for 2021-2030, which moves away from vertical disease programmes to integrated cross-cutting approaches. The aim is to facilitate the coordinated scale-up of key interventions through public health approaches such as preventive chemotherapy, individual case management, vector control, veterinary public health and water, sanitation and hygiene (WASH) (WHO, no date c).

The overarching 2030 global targets include a 90% reduction in the number of people requiring treatment for NTDs; a 75% reduction in DALYs related to NTDs; at least 100 countries eliminating at least one NTD; and the eradication of two diseases (dracunculiasis and yaws) (WHO, no date c).

Additional cross-cutting targets focus on integrated approaches, multisectoral coordination, universal health coverage and country ownership, while a further set of targets has been devised to measure progress against each disease (WHO no date c).

The WHO Roadmap on neglected tropical diseases, underpinned by successive World Health Assembly resolutions, sets out a comprehensive plan for the control, elimination and eradication of neglected tropical diseases by 2030 (WHO, 2021). The road map sets global targets and milestones to prevent, control, eliminate or eradicate 20 diseases and disease groups as well as cross-cutting targets aligned with the Sustainable Development Goals. Three foundational pillars will support global efforts to achieve the targets: accelerate programmatic action (pillar 1), intensify cross-cutting approaches (pillar 2) and change operating models and culture to facilitate country ownership (pillar 3) (WHO, 2021). The disease summaries annexed to the road map detail the current epidemiological status and burden of disease, core strategic interventions and progress towards the 2020 targets of the previous road map (WHO, 2021). The targets, sub-targets and milestones for 2030, and the critical actions required to achieve them, were used to generate the evidence in the road map document endorsed by the World Health Assembly (WHO, 2021).

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0106 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Sexually Transmitted Infections (Human)

Definition

Sexually transmitted infections are transmitted through sexual contact, including vaginal, anal and oral sex and some can also be transmitted from mother-to-child during pregnancy, childbirth and breastfeeding (WHO, 2024).

Reference

WHO, 2024. Sexually Transmitted Infections (STIs). Fact Sheet. World Health Organization (WHO). www.who.int/news-room/fact-sheets/detail/sexually-transmitted-infections-(stis) Accessed 17 February 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Sexually transmitted infections, STIs. Venereal diseases.

Additional scientific description

Sexually transmitted diseases (STDs) are spread predominantly by sexual contact, including vaginal, anal and oral sex. Some sexually transmitted diseases can also be transmitted through non-sexual means such as via blood or blood products. Many sexually transmitted diseases, including syphilis, hepatitis B, human immunodeficiency virus (HIV), chlamydia, gonorrhoea, herpes, and human papillomavirus (HPV), can also be transmitted from mother to child during pregnancy and childbirth. STIs have a direct impact on sexual and reproductive health through stigmatization, infertility, cancers and pregnancy complications and can increase the risk of HIV. Drug resistance is a major threat to reducing the burden of STIs worldwide (WHO, 2024).

More than 30 different bacteria, viruses and parasites are known to be transmitted through sexual contact, including vaginal, anal and oral sex. Some STIs can also be transmitted from mother-to-child during pregnancy, childbirth and breastfeeding. Eight pathogens are linked to the greatest incidence of STIs. Of these, 4 are currently curable: syphilis, gonorrhoea, chlamydia and trichomoniasis. The other 4 are viral infections: hepatitis B, herpes simplex virus (HSV), HIV and human papillomavirus (HPV) (WHO, 2024).

In addition, emerging outbreaks of new infections that can be acquired by sexual contact such as mpox, *Shigella sonnei*, *Neisseria meningitidis*, Ebola and Zika, as well as re-emergence of neglected STIs such as lymphogranuloma venereum. These herald increasing challenges in the provision of adequate services for STI prevention and control.

Metrics and numeric limits

More than 1 million curable STIs are acquired every day. In 2020, WHO estimated 374 million new infections with 1 of 4 STIs: chlamydia (129 million), gonorrhoea (82 million), syphilis (7.1 million) and trichomoniasis (156 million). More than 490 million people were estimated to be living with genital herpes in 2016, and an estimated 300 million women have an HPV infection, the primary cause of cervical cancer and anal cancer among men who have sex with men. In addition, updated WHO estimates indicate that 254 million people were living with hepatitis B in 2022 (WHO, 2024).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016a).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: More than 30 different bacteria, viruses and parasites are known to be transmitted through sexual contact, including vaginal, anal and oral sex. Some STIs can also be transmitted from mother-to-child during pregnancy, childbirth and breastfeeding (WHO, 2024).

Impacts: STIs have a profound impact on sexual and reproductive health worldwide (WHO, 2024). STIs can have serious consequences beyond the immediate impact of the infection itself:

- STIs like herpes, gonorrhoea and syphilis can increase the risk of HIV acquisition.
- Mother-to-child transmission of STIs can result in stillbirth, neonatal death, low birthweight and prematurity, sepsis, neonatal conjunctivitis and congenital deformities.
- HPV infection causes cervical and other cancers.
- Hepatitis B resulted in just over 1 million deaths in 2022, mostly from cirrhosis and hepatocellular carcinoma.
- STIs such as gonorrhoea and chlamydia are major causes of pelvic inflammatory disease and infertility in women.

People seeking screening and treatment for STIs face numerous problems. These include limited resources, stigmatization, poor quality of services and often out-of-pocket expenses. Some populations with the highest rates of STIs – such as sex workers, men who have sex with men, people who inject drugs, prison inmates, mobile populations and adolescents in high-burden countries for HIV – often do not have access to adequate and friendly health services. In many settings, STI services are often neglected and underfunded. These problems lead to difficulties in providing testing for asymptomatic infections, insufficient number of trained personnel, limited laboratory capacity and inadequate supplies of appropriate medicines (WHO, 2024).

Multi-hazard Context: Despite ongoing efforts to identify simple interventions to reduce risky sexual behaviour, information, education, and counselling continue to play a key role. These strategies can improve people's ability to recognise STI symptoms, increase the likelihood that they will seek care, and encourage their sexual partners to do the same. However, limited public awareness, insufficient training among health workers, and persistent stigma surrounding STIs remain major barriers to the effective use of these interventions (WHO, 2024).

Monitoring: WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date).

Risk Management: Effective treatment is currently available for several STIs (WHO 2024):

- Three bacterial (chlamydia, gonorrhoea and syphilis) and one parasitic STIs (trichomoniasis) are generally curable with existing single-dose regimens of antibiotics.
- For herpes and HIV, the most effective medications available are antivirals that can modulate the course of the disease, though they cannot cure the disease.
- For hepatitis B, antivirals can help in fighting the virus and slowing down damage to the liver.

Antimicrobial resistance (AMR) of STIs – in particular gonorrhoea – has increased rapidly in recent years and has reduced treatment options. The Gonococcal AMR Surveillance Programme (GASP) has shown high rates of resistance to many antibiotics including quinolone, azithromycin and extended-spectrum cephalosporins, a last-line treatment. AMR for other STIs, like *Mycoplasma genitalium*, also exist but are not systematically monitored (WHO, 2024).

Safe and highly effective vaccines are available for 2 viral STIs: hepatitis B and HPV. These vaccines have represented major advances in STI prevention. By the end of 2023, the HPV vaccine had been introduced as part of routine immunization programmes in 140 countries, primarily high- and middle-income countries. To eliminate cervical cancer as a public health problem globally, high coverage targets for HPV vaccination, screening and treatment of precancerous lesions, and management of cancer must be reached by 2030 and maintained at this high level for decades. Research to develop vaccines against genital herpes is advanced, with several vaccine candidates in early clinical development.

Preliminary – Corrections Pending

There is mounting evidence suggesting that the vaccine to prevent meningitis (MenB) provides some cross-protection against gonorrhoea. More research into vaccines for chlamydia, gonorrhoea, syphilis and trichomoniasis is needed (WHO, 2024).

Antimicrobial resistance to sexually transmitted diseases, in particular gonorrhoea, has increased rapidly in recent years, making preventative approaches such as counselling and access to barrier methods an important part of effective risk management for these diseases (WHO, no date).

WHO work is currently guided by the Global health sector strategy on HIV, Hepatitis and Sexually Transmitted Infections, 2022-2030 (WHO, 2022). Within this framework, WHO:

- develops global targets, norms and standards for STI prevention, testing and treatment;
- supports the estimation and economic burden of STIs and the strengthening of STI surveillance;
- globally monitors AMR to gonorrhoea; and
- leads the setting of the global research agenda on STIs, including the development of diagnostic tests, vaccines and additional drugs for gonorrhoea and syphilis.

As part of its mission, WHO supports countries to:

- develop national strategic plans and guidelines;
- create an encouraging environment allowing individuals to discuss STIs, adopt safer sexual practices, and seek treatment;
- scale-up primary prevention (condom availability and use, etc.);
- increase integration of STI services within primary healthcare services;
- increase accessibility of people-centred quality STI care;
- facilitate adoption of point-of-care tests;
- enhance and scale-up health intervention for impact, such as hepatitis B and HPV vaccination, syphilis screening in priority populations;
- strengthen capacity to monitor STIs trends; and
- monitor and respond to AMR in gonorrhoea (WHO. 2024).

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0107 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Vaccine-Preventable Diseases (Human)

Definition

Vaccine-preventable diseases are those infectious diseases that can be prevented by vaccination (WHO, 2019).

Reference

WHO, 2019. Vaccine-preventable diseases and vaccines. In: International Travel and Health, Chapter 6. World Health Organization (WHO). https://www.who.int/publications/m/item/international-travel-and-health-chapter-6---vaccine-preventable-diseases-and-vaccines Accessed 17 February 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Not identified.

Additional scientific description

Immunisation, the use of vaccines to produce immunity to specific diseases, is a global health and development success story, saving millions of lives every year. Vaccination is a highly effective method of preventing certain infectious diseases. Vaccines reduce the risks of getting a disease by working with each individual's natural defences to build protection (WHO, no date a).

Health care now has vaccines to prevent more than 20 life-threatening diseases, helping people of all ages live longer, healthier lives. Immunisation currently prevents 3.5 million to 5 million deaths every year from diseases such as diphtheria, tetanus, pertussis, influenza and measles (WHO, no date a). Immunisation is a key component of primary health care and an indisputable human right. It is also one of the most cost-effective health investments. Vaccines are also critical to the prevention and control of infectious disease outbreaks. They underpin global health security and are a vital tool in the battle against antimicrobial resistance (WHO, no date).

The COVID-19 pandemic strained health systems, resulting in dramatic setbacks. The most recent data for diphtheria-pertussis-tetanus (DTP) immunization coverage underscores the need for ongoing catch-up, recovery and system-strengthening (WHO, no date a).

Measles, because of its high transmissibility, acts as a "canary in the coalmine", quickly exposing immunity. In 2023, the routine first dose of measles vaccine was missed by 22 million children – far from the 2019 level of 19.3 million children. Globally in 2023, there were 14.5 million children missing out on any vaccination – so-called zero-dose children (WHO, 2024).

Available vaccines protect against many diseases, including:

- Cholera (BI0204)
- COVID-19 (corona virus) (BI0205)
- Dengue (BI0207)
- Diphtheria (BI0208)
- Hepatitis A (BI0211)
- Hepatitis B (BI0212)
- Haemophilus influenzae type b (Hib)
- Human papillomavirus (HPV)
- Influenza (BI0243)
- Japanese encephalitis
- Malaria (BI0219)
- Measles (BI0221)
- Meningococcal meningitis (BI0222)

- Mumps
- Pertussis (BI0227)
- Pneumococcal disease
- Poliomyelitis (BI0229)
- Rabies (BI0232)
- Rotavirus (BI0233)
- Rubella
- Tetanus
- Tick-borne encephalitis
- Tuberculosis (BI0237)
- Typhoid (BI0226)
- Varicella
- Yellow Fever (BI0241) (WHO, no date a)

'Pipeline vaccines' are in development for other pathogens (WHO, no date a).

Metrics and numeric limits

Immunisation currently prevents 3.5 million to 5 million deaths every year from diseases such as diphtheria, tetanus, pertussis, influenza and measles (WHO, no date a).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: The most common sociodemographic determinants associated with the reduction of vaccination uptake were economic status, age, education, and household composition (Eiden et al., 2022).

Impacts: Globally in 2023, there were 14.5 million children missing out on any vaccination – so-called zero-dose children (WHO, 2024). The most common sociodemographic determinants associated with the reduction of vaccination uptake were economic status, age, education, and household composition (Eiden et al., 2022).

Multi-hazard Context: Vaccine refusal not only increases the individual risk of disease but also increases the risk for the whole community (Omer et al, 2009). Issues with regard to the burden of disease mortality, disease transmission, and available vaccines as well as vaccine successes and shortcomings for specific pathogens can serve as important landmarks for effective use of future vaccines (Frankel, 2021).

Monitoring: WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021 c).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a disaster from natural hazards. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023).

Risk Management: Vaccines reduce the risks of getting a disease by working with each individual's natural defences to build protection (WHO, no date a). Health care now has vaccines to prevent more than 20 life-threatening diseases, helping people of all ages live longer, healthier lives. Immunisation currently prevents 3.5 million to 5 million deaths every year from diseases such as diphtheria, tetanus, pertussis, influenza and measles (WHO, no date a).

WHO is working with countries and partners to improve global vaccination coverage, including through these initiatives adopted by the World Health Assembly in August 2020.

Immunization Agenda 2030 (IA2030) sets an ambitious, overarching global vision and strategy for vaccines and immunization for the decade 2021-2030 (WHO, 2020). It was co-created with thousands of contributions from countries and organizations around the world. It draws on lessons from the past decade and acknowledges continuing and new challenges posed by infectious diseases (e.g. Ebola, COVID-19) (WHO, no date a).

The strategy has been designed to respond to the interests of every country and intends to inspire and align the activities of community, national, regional and global stakeholders towards achieving a world where everyone, everywhere fully benefits from vaccines for good health and well-being. IA2030 is operationalized through regional and national strategies, and a

Preliminary – Corrections Pending

mechanism to ensure ownership and accountability and a monitoring and evaluation framework to guide country implementation (WHO, 2021).

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0108 / BIOLOGICAL / Infectious Diseases

zoonosis

Vector-borne diseases (VBD) (Human and Animal)

Definition

Vector-borne diseases encompass a variety of illnesses that are caused by the spread of pathogens by living organisms known as vectors. These infectious diseases can be transmitted via vectors among humans (e.g. malaria, dengue), among animals (e.g. African swine fever, East Coast fever), or from animals to humans (e.g. Nipah virus disease). Many of these vectors are bloodsucking insects, and mosquitoes are the best-known disease vectors. Other vectors include ticks, flies, sandflies, fleas, triatomine bugs and some species of freshwater aquatic snails (adapted from WOAH, 2024a; WHO, 2024).

Reference

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Preliminary – Corrections Pending

Annotations

Synonyms

Arthropod-borne diseases, vector-transmitted diseases, vector diseases.

Additional scientific description

Vectors are living organisms that can transmit infectious pathogens between humans, or from animals to humans. Many of these vectors are bloodsucking insects, which ingest disease-producing microorganisms during a blood meal from an infected host (human or animal) and later transmit it into a new host, after the pathogen has replicated. Often, once a vector becomes infectious, they are capable of transmitting the pathogen for the rest of their life during each subsequent bite/blood meal (WHO, 2020).

VBDs included in the HIPs: Plague (BI0228), Chikungunya (BI0203), Zika Virus (BI0242), Yellow Fever (BI0241), Dengue (BI0207), Malaria (BI0219), Crimean-Congo Haemorrhagic Fever (BI0206), African Swine Fever (BI0301), Lumpy Skin Disease (BI0307), Q Fever (BI0231), Rift Valley Fever (BI0311), Trypanosomiasis (BI0238), West Nile Fever (BI0240), Yellow Fever (BI0241), Zika (BI0242).

Human

Vector-borne diseases are human illnesses caused by parasites, viruses and bacteria that are transmitted by vectors. Every year there are more than 700 000 deaths from diseases such as malaria, dengue, schistosomiasis, human African trypanosomiasis, leishmaniasis, Chagas disease, yellow fever, Japanese encephalitis and onchocerciasis. The burden of these diseases is highest in tropical and subtropical areas, and they disproportionately affect the poorest populations. Since 2014, major outbreaks of dengue, malaria, yellow fever and Zika have afflicted populations, claimed lives, and overwhelmed health systems in many countries. Other diseases such as chikungunya, leishmaniasis and lymphatic filariasis cause chronic suffering, life-long morbidity, disability and occasional stigmatization (WHO, 2024).

Many of the vectors are bloodsucking insects which ingest disease-producing microorganisms during a blood meal from an infected host (human or animal) and later transmit it into a new host, after the pathogen has replicated. Often, once a vector becomes infectious, they are capable of transmitting the pathogen for the rest of their life during each subsequent bite/blood meal (WHO, 2024).

Vector-borne diseases account for more than 17% of all infectious diseases, causing more than 700,000 deaths annually. They may be caused by parasites, bacteria or viruses (WHO, 2020). Examples of vector borne diseases include:

- Malaria is a parasitic infection transmitted by Anopheline mosquitoes. Malaria causes an estimated 219 million cases globally, and results in more than 400,000 deaths every year. Most of the deaths occur in children under the age of 5 years (WHO, 2020).
- Dengue is the most prevalent viral infection transmitted by Aedes mosquitoes. More than 3.9 billion people in over 129 countries are at risk of contracting dengue, with an estimated 96 million symptomatic cases and an estimated 40,000 deaths every year (WHO, 2020).

- Other viral diseases transmitted by vectors include chikungunya fever, Zika virus fever, yellow fever, West Nile fever, Japanese encephalitis (all transmitted by mosquitoes), and tick-borne encephalitis (transmitted by ticks) (WHO, 2020).
- Other vector-borne diseases such as Chagas disease (transmitted by triatomine bugs), leishmaniasis (sandflies) and schistosomiasis (snails) affect hundreds of millions of people worldwide (WHO, 2020).

The table is a non-exhaustive list of vector-borne diseases, ordered according to the vector by which it is transmitted. The list also illustrates the type of pathogen that causes the disease in humans (WHO, 2020):

Vector		Disease caused	Type of pathogen
Mosquito	Aedes	Chikungunya	Virus
		Dengue	Virus
		Lymphatic filariasis	Parasite
		Rift Valley fever	Virus
		Yellow Fever	Virus
		Zika	Virus
	Anopheles	Lymphatic filariasis	Parasite
		Malaria	Parasite
	Culex	Japanese encephalitis	Virus
		Lymphatic filariasis	Parasite
		West Nile fever	Virus
Aquatic snails		Schistosomiasis (bilharziasis)	Parasite
Blackflies		Onchocerciasis (river blindness)	Parasite
Fleas		Plague (transmitted from rats to humans)	Bacteria
		Tungiasis	Ectoparasite
Lice		Typhus	Bacteria
		Louse-borne relapsing fever	Bacteria
Sandflies		Leishmaniasis	Bacteria
		Sandfly fever (phlebotomus fever)	Virus
Ticks		Crimean-Congo haemorrhagic fever	Virus
		Lyme disease	Bacteria
		Relapsing fever (borreliosis)	Bacteria
		Rickettsial diseases (e.g. spotted fever and Q fever)	Bacteria
		Tick-borne encephalitis	Virus
		Tularaemia	Bacteria
Triatome bugs		Chagas disease (American trypanosomiasis)	Parasite
Tsetse flies		Sleeping sickness (African trypanosomiasis)	Parasite

Animal

Vector-borne animal diseases include:

- Crimean-Congo Haemorrhagic Fever (BI0206)
- African Swine Fever (BI0302)
- Lumpy Skin Disease (BI0307)
- New World Screwworm (NWS) (BI0309)
- Rift Valley Fever (BI0311)
- West Nile Fever (BI0240)
- Trypanosomiasis / African Trypanosomosis (BI0238)

Many VBDs in animals are preventable through control measures, including vaccination. Most countries maintain a list of approved veterinary vaccines for use. For specific regulations, consult the country's veterinary authorities (FAO, 2021).

Metrics and numeric limits

Vector-borne diseases account for more than 17% of all infectious diseases, causing more than 700,000 deaths annually. They can be caused by either parasites, bacteria or viruses (WHO, 2024).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) (WTO, 1994). https://www.wto.org/english/res_e/booksp_e/agrmntseries4_sps_e.pdf Accessed 1 January 2025.

Preliminary – Corrections Pending

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UN Recommendations on the Transport of Dangerous Goods - UN Model Regulations Model Regulations Nature, Purpose and Significance of the Recommendations (UNECE, no date). https://unece.org/transport/dangerous-goods/un-model-regulations-rev-23 Accessed 1 January 2025.

The Global Vector Control Response 2017-2030 (GVCR) provides a new strategy to strengthen vector control worldwide through increased capacity, improved surveillance, better coordination and integrated action across sectors and diseases.

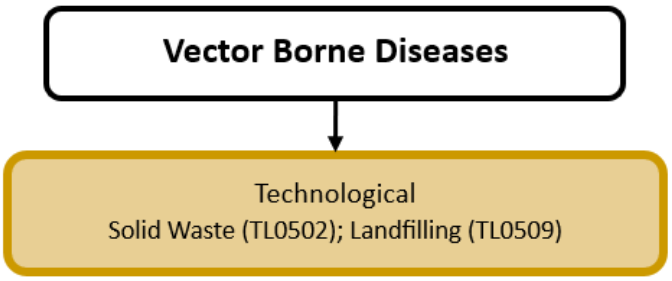
Terrestrial Animal Health Code. 32nd edition. World Organisation for Animal Health (WOAH) (WOAH, 2024b).

In May 2017, the World Health Assembly adopted resolution WHA 70.16, which calls on Member States to develop or adapt national vector control strategies and operational plans to align with this strategy (WHO, 2017).

Examples of hazard drivers, impacts, and risk management

Human
Hazard Drivers: Previously relatively stable geographical distributions are now changing owing to a range of factors, including climate change, intensive farming, dams, irrigation, deforestation, population movements, rapid unplanned urbanisation, and phenomenal increases in international travel and trade (WHO, 2014). The distribution of vector-borne diseases in humans is determined by a complex set of demographics, and environmental and social factors. Global travel and trade, unplanned urbanization, climate change and silent spread and adaptation of the vectors have all contributed to the spread of vector-borne diseases. Climate change substantially affects pathogens (parasites, viruses and bacteria), vectors, and reservoir hosts, with implications for the transmission of many vector-borne diseases. Several vectors have expanded their latitude and altitude ranges, and the length of the season during which they are active is increasing. These trends are expected to continue as the climate continues to get warmer (WHO, 2024). Climate-driven fluctuations in environmental conditions, such as drought, flood, rainfall, wind and unpredictable weather have a direct influence on the disease burden from bacteria, parasites and their vectors. Work is being carried out to improve prevention, preparedness, early detection and early response to animal health threats and emergencies that could be triggered by climate change (FAO, 2020). **Impacts**: Vector-borne disease generates disease in humans after consuming unheated dairy products (e.g., raw milk); and trade implications. These may involve substantial economic losses, including loss of income and manpower, medical care costs, and loss of food due to inadequacy of processing or spoilage.
Animal
Hazard Drivers: Vector-borne diseases infected mosquitoes (OIE, 2015a). **Impacts**: High fever, abortion, and depending on the pathogen, death of infected animals and humans, spread of infection, trade/travel ban (OIE, 2015b).

Multi-hazard Context: The figure below summarises common interactions between vector-borne diseases and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring for vector-borne diseases. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

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WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023).

Which institution(s) produce(s) Disaster Risk Data/Information?	WHO, Ministry of Health, FAO Reference Centres, WOAH Reference Centres
How is the Hazard Observed/Monitored/Forecast?	WHO, Ministry of Health, FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

Risk Management

Human

Risk Management: Many vector-borne diseases are preventable, through protective measures, and community mobilisation (WHO, 2020).

The World Health Organization (WHO) has taken forward the Global Vector Control Response (GVCR) 2017–2030 (WHO, 2017) which was approved by the World Health Assembly in 2017. It provides strategic guidance to countries and development partners for the urgent strengthening of vector control as a fundamental approach to preventing disease and responding to outbreaks. To achieve this a re-alignment of vector control programmes is required, supported by increased technical capacity, improved infrastructure, strengthened monitoring and surveillance systems, and greater community mobilisation. Ultimately, this will support the implementation of a comprehensive approach to vector control that will enable the achievement of disease-specific national and global goals and contribute to the achievement of the Sustainable Development Goals (UN, 2015) and Universal Health Coverage (WHO, 2020). Specifically, the WHO responds to vector-borne diseases by: providing evidence-based guidance for controlling vectors and protecting people against infection; providing technical support to countries so that they can effectively manage cases and outbreaks; supporting countries to improve their reporting systems and capture the true burden of the disease; providing training (capacity building) on clinical management, diagnosis and vector control with support from some of its collaborating centres; and supporting the development and evaluation of new tools, technologies and approaches for vector-borne diseases, including vector control and disease management technologies (WHO, 2020).

A crucial element in reducing the burden of vector-borne diseases is behavioural change. The WHO works with partners to provide education and improve public awareness, so that people know how to protect themselves and their communities from mosquitoes, ticks, bugs, flies and other vectors (WHO, 2020).

Access to water and sanitation is a very important factor in disease control and elimination. The WHO works together with many different government sectors to improve water storage and sanitation, thereby helping to control these diseases at the community level (WHO, 2020).

Rapid progress has been made in recent years in developing policy mandates, operational frameworks and pilot initiatives on health adaptation to climate change, including vector-borne disease as a particular priority. These present an excellent opportunity for a stronger and more coherent connection between applied research and public health policy (Campbell-Lendrum et al., 2015).

Applied research is nevertheless essential to ensure continued progress in reducing the burden of vector-borne diseases in the face of the additional challenges caused by anthropogenic climate change, along with rapid changes in other environmental and social determinants. To increase relevance to current health programming, there is a need to complement current work on the detection and attribution of health effects to climate change, and the modelling of future scenarios, with a more directly applied approach to assessing and managing climate-related risks in the present (Campbell-Lendrum et al., 2015).

Progress has been made in recent years in developing policies, operational frameworks and pilot initiatives on animal health-based adaptation to climate change, with vector-borne diseases as a priority. These represent excellent opportunities for stronger and more coherent linkages between applied research and public health policy (Campbell-Lendrum et al., 2015).

Animal

Risk Management: vaccination programme, movement control, improve biosecurity (OIE, 2015b). Climate-driven fluctuations in environmental conditions, such as drought, flood, rainfall, wind and unpredictable weather have a direct influence on the disease burden from bacteria, parasites and their vectors. Work is being carried out to improve prevention, preparedness, early detection and early response to animal health threats and emergencies that could be triggered by climate change (FAO, 2020). Progress has been made in recent years in developing policies, operational frameworks and pilot initiatives on animal health-based adaptation to climate change, with vector-borne diseases as a priority. These represent excellent opportunities for stronger and more coherent linkages between applied research and public health policy (Campbell-Lendrum et al., 2015).

Preliminary – Corrections Pending

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Coordinating agency or organisation

World Health Organization (WHO), Food and Agriculture Organization of the United Nations (FAO) and World Organisation for Animal Health (WOAH).

Preliminary – Corrections Pending

BI0109 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Viral Haemorrhagic Fevers (Human)

Definition

Viral haemorrhagic fevers include a spectrum of relatively mild to severe life-threatening diseases characterized by sudden onset of muscle and joint pain, fever, bleeding and shock from loss of blood. In severe cases, one of the most prominent symptoms is bleeding, or haemorrhaging, from orifices and internal organs (WHO, no date a).

Reference

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Preliminary - Corrections Pending

Annotations

Synonyms

VHF

Additional scientific description

Viral haemorrhagic fevers (VHF) include a spectrum of relatively mild to severe life-threatening diseases characterized by sudden onset of muscle and joint pain, fever, bleeding and shock from loss of blood. In severe cases, one of the most prominent symptoms is bleeding, or haemorrhaging, from orifices and internal organs (WHO, no date a).

VHF are associated with the occurrence of major epidemics with high case-fatality rates owing to the fact that there are no specific medical countermeasures such as vaccines or antivirals, the exception being yellow fever. Lack of timely laboratory diagnosis, late detection, inadequate infection control practices at health care facilities, and weak vector control programmes could also prolong outbreaks of haemorrhagic fevers.

Viral haemorrhagic fever (VHF) diseases are caused by 3 families (Arenaviridae, Filoviridae, Flaviviridae) and 1 order (Bunyavirales) of enveloped RNA viruses (CDC, 2024). Most VHFs fall into one of four families of virus:

- Arenaviruses - Each arenavirus has one or a few closely related rodents that carry the virus without getting sick themselves. This is known as the reservoir, or source of the virus in nature. The reservoir can spread the virus to people through infected urine, saliva, or droppings, and can cause severe disease in people. People are infected with arenaviruses by:
  - Touching with rodent urine, droppings, or nesting materials from an infected rodent
  - Breathing in air contaminated by rodent urine, droppings or nesting materials.
  - Being bitten or scratched by an infected rodent.
  - Eating food contaminated by urine, droppings, or saliva from an infected rodent.
  - Contact with another person who has certain arenaviruses, such as Chapare, Lassa, Machupo, and Lujo viruses. (CDC, 2024).
- Bunyavirales order - Viruses in the Bunyavirales order are spread by rodents or insects, such as mosquitos, ticks, or sand flies. They can produce mild to severe disease in animals and people. Many of these viruses cannot spread between people. However, person -to person spread of Crimean-Congo haemorrhagic fever has occurred in healthcare settings where infection control was limited (CDC, 2024).
- Filoviruses can cause severe illness in people and nonhuman primates (such as monkeys and gorillas). The Egyptian rousette bat, *Rousettus aegyptiacus,* is a cave-dwelling bat, and the reservoir for Marburg virus. Bats infected with orthomarburgviruses do not show obvious signs of illness. It's not known what animal carries ebolaviruses in nature, but scientists suspect that bats are likely involved. Once filoviruses are introduced into the human population, they can spread between people through contact

with an infected person's body fluids. Caretakers and healthcare providers who do not use appropriate personal protective equipment (PPE) are at higher risk of infection (CDC, 2024).

- Flaviviruses are found throughout the world. These viruses, which are primarily spread by mosquitoes and ticks, can cause mild to severe disease or even death. They can also cause disease in animals, creating a large economic and social impact on people living in affected areas (CDC, 2024).
- Paramyxoviruses can cause sudden onset of respiratory disease. While there are many viruses included within the *Paramyxoviridae* family, Hendra and Nipah viruses are considered more serious because they require a specialized lab, (biosafety level 4 lab) and can cause serious disease, spread between animals and people, and have no vaccine or treatment currently available (CDC, 2024),

Most VHFs fall into one of four families of virus:

Arenavirus (order Bunyavirales)

- Lassa fever virus (BI0215)
- Lujo virus
- Junin virus
- Chapare virus
- Sabia virus
- Machupo virus
- Guanarito virus

Filoviruses

- Ebola virus (EBOV) (BI0209)
- Sudan virus (SUDV)
- Bundibugyo virus (BDBV)
- Taï Forest virus (TAFV)
- Marburg virus (MARV) NEW HIP
- Ravn virus

Flavirviruses

- Alkhurma hemorrhagic fever virus
- Kyasanur Forest Disease virus
- Omsk Hemorrhagic Fever virus
- Dengue virus (BI0207)
- Yellow Fever virus (BI0241)

Bunyavirales order

- Hantavirus (Bunyavirales) Hantaviruses
- Nairovirus (order Bunyavirales) Crimean-Congo Haemorrhagic Fever virus (BI0206)
- Phenuvirus (Bunyavirales) Rift Valley Fever virus (BI0311)

Paramyxoviruses

- Hendra virus
- Nipah virus (CDC, 2024)

Several viral haemorrhagic fevers are prone to outbreaks and epidemics with high case fatality rates. These include Ebola, Lassa fever and Crimean-Congo haemorrhagic fever. These diseases are part of the priority list for the World Health Organization (WHO) WHO research and development (R&D) Blueprint for Epidemics (WHO, 2024).

Preliminary – Corrections Pending

Metrics and numeric limits

The WHO Global Clinical Platform aims to understand the clinical features, prognostic factors and outcomes from viral haemorrhagic fever, focussing on filovirus infection. Data contributed to the platform helps WHO to support member states in understanding the health problems from national and international perspectives. Health care facilities/collaborators around the world have contributed clinical data to the WHO Clinical Data Platform. (WHO, no date b; WHO, no date c)

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016b).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Viral haemorrhagic fevers occur widely in tropical and subtropical regions (WHO, no date). Most of them have a non-human natural reservoir, with some transmitted by mosquitoes or ticks. A small number are preventable by vaccine (e.g., yellow fever) and others have potential vaccines and treatments in different stages of development (WHO, no date a).

Impacts: VHF are associated with the occurrence of major epidemics with high case-fatality rates, owing to the fact that there are no specific medical countermeasures such as vaccines or antivirals, the exception being yellow fever. Lack of timely laboratory diagnosis, late detection, inadequate infection control practices at health care facilities, and weak vector control programmes could also prolong outbreaks of haemorrhagic fevers. (WHO, no date)

The emergence and re-emergence of viral haemorrhagic fevers is a growing concern worldwide and there are multiple modes of transmission for viral haemorrhagic fever:

- person to person through direct contact with symptomatic patients, body fluids, or cadavers
- inadequate infection control in a hospital setting (Crimean-Congo haemorrhagic fever, Lassa, Ebola)
- slaughtering practices
- consumption of raw meat from infected animals or unpasteurized milk (Crimean-Congo haemorrhagic fever, Rift Valley fever)
- direct contact with rodents, or inhalation of or contact with materials contaminated with rodent excreta (Lassa)
- mosquito bites (Rift Valley fever, Dengue) or ticks (Crimean-Congo haemorrhagic fever) (WHO EMRO, no date).

Multi-hazard Context: Varies with individual diseases

Effective VHF surveillance and control also require international cooperation, bridging gaps between various scientific disciplines and public health initiatives. By pooling knowledge, resources, and strategies on a global scale, the international health community can forge comprehensive and pre-emptive responses to VHF outbreaks. Moreover, local community engagement plays a critical role in the successful implementation of surveillance and control measures. Here, understanding local cultural practices and perceptions of disease is key to designing interventions that are not only effective, but also culturally sensitive and accepted (Hewson, 2024).

Employing advanced technologies like GIS, remote sensing, and genomic sequencing enhances the capability to monitor and analyse the spread and transmission patterns of VHFs in rea-time. Such tools are key to gathering data and generating insights that drive effective public health interventions (Hewson, 2024).

Monitoring: WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date b).

Risk Management: WHO has created a Global Clinical Platform of patient-level anonymized clinical data. It is a secure, limited-access, password-protected platform hosted on REDCap (WHO no date c). The objectives of the Platform are to:

- describe the clinical characterization of a disease, its natural history and severity;
- identify the association of clinical characteristics of viral haemorrhagic fevers with outcomes; and
- enable an understanding of the clinical resource-use when providing high-quality supportive care (WHO no date b).

Previous versions of this platform have captured data for individual viral haemorrhagic fevers, for example, Marburg Virus Disease, Ebola Virus Disease and Sudan Virus Disease. This latest version aims to be a common tool which can be used in these and other illnesses and may allow future comparison between viral diseases. WHO invites Member States, health facilities and other entities to participate in the global effort to collect anonymized clinical data relating to suspected or confirmed cases of viral haemorrhagic fever and contribute data to the WHO Global Clinical Platform (WHO no date c).

The WHO R&D Blueprint for Epidemics functions as a global platform for research and development collaboration, stressing the significance of international cooperation in expediting the research and development of medical countermeasures (MCMs) to respond to epidemics and pandemics. At the core of its efforts lies the concept of 'pathogen prioritization'. Several VHF have been identified as priorities for research to generate results to inform regulatory assessment and policy decisions, while ensuring that national and individual interests are respected. Such simple protocols can be integrated into the outbreak response (WHO, 2024).

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Coordinating agency or organisation

World Health Organization.

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BI0110 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Waterborne Diseases

Definition

Contaminated water and poor sanitation are linked to transmission of diseases such as cholera, diarrhoea, dysentery, hepatitis A, hepatitis E, typhoid and polio (adapted from WHO, 2023a and WHO, 2023b).

Reference

WHO, 2023 a. Drinking-water. World Health Organization (WHO). https://www.who.int/news-room/fact-sheets/detail/drinking-water#:~:text=Water%20and%20health,hepatitis%20A%2C%20typhoid%20and%20polio. Accessed 26 February 2025.

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Annotations

Synonyms

Water-related diseases, Waterborne infections, Diseases transmitted by water, Water-borne illnesses.

Additional scientific description

Safe and readily available water is important for public health, whether it is used for drinking, domestic use, food production or recreational purposes. Improved water supply and sanitation, and better management of water resources, can boost countries' economic growth and can contribute greatly to poverty reduction (WHO, 2023a).

In 2010, the UN General Assembly explicitly recognized the human right to water and sanitation. Everyone has the right to sufficient, continuous, safe, acceptable, physically accessible and affordable water for personal and domestic use.

Diarrhoeal disease is the third leading cause of death in children 1-59 months of age. It is both preventable and treatable. Each year diarrhoea kills around 443,832 children under 5 and an additional 50,851 children aged 5 to 9 years. A significant proportion of diarrhoeal disease can be prevented through safe drinking water and adequate sanitation and hygiene. Globally, there are nearly 1.7 billion cases of childhood diarrhoeal disease every year. Diarrhoea is a leading cause of malnutrition in children under 5 years old (WHO, 2024).

Diarrhoea is defined as the passage of 3 or more loose or liquid stools per day (or more frequent passage than is normal for the individual). Frequent passing of formed stools is not diarrhoea, nor is the passing of loose, pasty stools by breastfed babies. Diarrhoea is usually a symptom of an infection in the intestinal tract, which can be caused by a variety of bacterial, viral and parasitic organisms. Infection spreads through contaminated food or drinking-water, or from person to person as a result of poor hygiene (WHO, 2024). Chemical irritation of the gut or non-infectious bowel disease can also result in diarrhoea.

Contaminated water and poor sanitation are linked to transmission of diseases such as cholera, diarrhoea, dysentery, hepatitis A, typhoid and polio (WHO, 2023a). Diarrhoea is the most widely known disease linked to contaminated food and water but there are other hazards. In 2021, over 251.4 million people required preventative treatment for schistosomiasis - an acute and chronic disease caused by parasitic worms contracted through exposure to infested water (WHO, 2023a). Inadequate management of urban, industrial and agricultural wastewater means the drinking water of hundreds of millions of people is dangerously contaminated or chemically polluted. The natural presence of chemicals, particularly in groundwater, can also be of health significance, including arsenic and fluoride, while other chemicals, such as lead, may

be elevated in drinking water as a result of leaching from water supply components in contact with drinking water (WHO, 2023a).

Metrics and numeric limits

In 2022, globally, at least 1.7 billion people use a drinking water source contaminated with faeces. Microbial contamination of drinking-water as a result of contamination with faeces poses the greatest risk to drinking-water safety (WHO, 2023a).

Microbiologically contaminated drinking water can transmit diseases such as diarrhoea, cholera, dysentery, typhoid and polio and is estimated to cause approximately 505,000 diarrhoeal deaths each year (WHO, 2023a).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

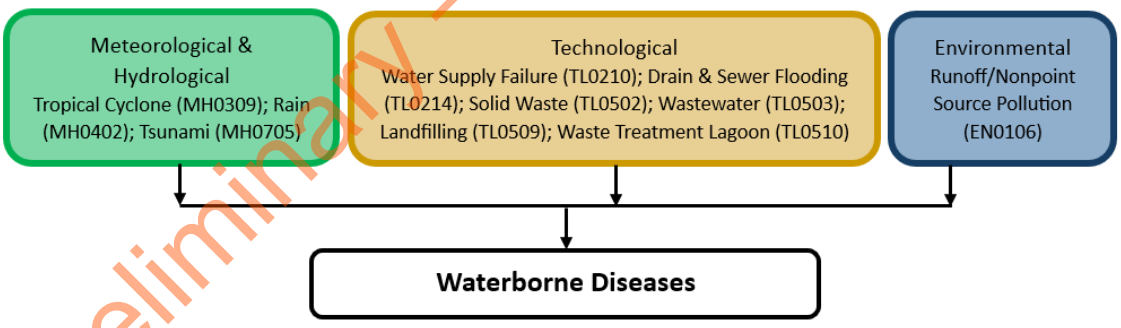
Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Absent, inadequate, or inappropriately managed water and sanitation services expose individuals to preventable health risks. This is particularly the case in health care facilities where both patients and staff are placed at additional risk of infection and disease when water, sanitation and hygiene services are lacking (WHO, 2023a). Out of every 100 patients in acute-care hospitals, 7 patients in high-income countries (HICs) and 15 patients in low- and middle-income countries (LMICs) will acquire at least one health care-associated infection during their hospital stay (WHO, 2023a).

Impacts: Some 1 million people are estimated to die each year from diarrhoea as a result of unsafe drinking water, sanitation and hand hygiene. Yet diarrhoea is largely preventable, and the deaths of 395,000 children aged under 5 years could be avoided each year if these risk factors were addressed. Where water is not readily available, people may decide handwashing is not a priority, thereby adding to the likelihood of diarrhoea and other diseases (WHO 2023, a).

Sharp geographic, sociocultural and economic inequalities persist, not only between rural and urban areas but also in towns and cities where people living in low-income, informal or illegal settlements usually have less access to improved sources of drinking water than other residents.

Multi-hazard Context: The figure below summarises common interactions between waterborne diseases and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: Drinking-water surveillance is a core public health function and an integral component of the framework for safe drinking water recommended by the WHO Guidelines for drinking water quality. It is fundamental for the delivery of safe drinking water and the protection of public health by promoting the improvement of quality, quantity, accessibility, reliability, affordability and continuity of drinking water supplies. Risk-based drinking-water surveillance is considered best practice as it supports the development of appropriate and efficient monitoring programmes for individual supplies. It also aids prediction and identification of long-term changes and associated risks for drinking water supply (WHO, no date h).

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country's risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national

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disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date g)

Risk Management: In many parts of the world, insects that live or breed in water carry and transmit diseases such as dengue fever. Some of these insects, known as vectors, breed in clean, rather than dirty water, and household drinking water containers can serve as breeding grounds. The simple intervention of covering water storage containers can reduce vector breeding and may also reduce faecal contamination of water at the household level (WHO, 2023a).

As the international authority on public health and water quality, WHO leads global efforts to prevent the transmission of waterborne diseases. This is achieved by promoting health-based regulations to governments and working with partners to promote effective risk management practices to water suppliers, communities and households (WHO no date). Water safety and quality are fundamental to human development and well-being. Providing access to safe water is one of the most effective instruments in promoting health and reducing poverty (WHO, no date a).

WHO produces a series of water quality guidelines, including on drinking water, safe use of wastewater, and recreational water quality. The water quality guidelines are based on managing risks, and since 2004 the Guidelines for drinking-water quality promote the Framework for safe drinking water. The Framework recommends the establishment of health-based targets, the development and implementation of water safety plans by water suppliers to most effectively identify and manage risks from catchment to consumer, and independent surveillance to ensure that water safety plans are effective and health-based targets are being met (WHO, 2023a).

The drinking-water guidelines are supported by background publications that provide the technical basis for the Guidelines recommendations. WHO also supports countries in implementing the drinking-water quality guidelines through the development of practical guidance materials and the provision of direct country support. This includes the development of locally relevant drinking-water quality regulations aligned to the principles in the Guidelines, the development, implementation and auditing of water safety plans and strengthening of surveillance practices (WHO, 2023 a).

- Guidelines for drinking-water quality (WHO, 2022)
- Water Safety Plan resources (WHO, no date b)
- Developing drinking-water quality regulations and standards (WHO, no date c)
- Supporting publications to the Guidelines for drinking-water quality (WHO, no date e)

Since 2014, WHO has been testing household water treatment products against WHO health-based performance criteria through the WHO International Scheme to Evaluate Household Water Treatment Technologies (WHO no date e). The aim of the scheme is to ensure that products protect users from the pathogens that cause diarrhoeal disease and to strengthen policy, regulatory and monitoring mechanisms at the national level to support appropriate targeting and consistent and correct use of such products (WHO, 2023a).

WHO works closely with UNICEF in a number of areas concerning water and health, including water, sanitation, and hygiene in health-care facilities. In 2015 the two agencies jointly developed WASH FIT (Water and Sanitation for Health Facility Improvement Tool), an adaptation of the water safety plan approach. WASH FIT aims to guide small, primary health-care facilities in low- and middle-income settings through a continuous cycle of improvement through assessments, prioritization of risk, and definition of specific, targeted actions. A 2023 report describes practical steps that countries can take to improve water, sanitation and hygiene in health-care facilities (WHO, 2023b).

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Coordinating agency or organisation

World Health Organisation.

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BI0111 / BIOLOGICAL / Infectious Diseases (Human and Animal)

zoonosis

Cryptosporidium

Definition

Cryptosporidium is a microscopic parasite that can live in water, food, soil, or on surfaces that have been contaminated with infected faeces and causes the watery diarrhoeal disease cryptosporidiosis (adapted from CDC 2024 and Peletz et al., 2013).

References

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Annotations

Synonyms

Cryptosporidiosis, Crypto.

Additional scientific description

Human

Cryptosporidiosis is a diarrhoea-causing disease that is spread through germs that live in the faeces of infected people or animals. When a person swallows *Cryptosporidium*, or "Crypto" germs, they can become infected. Symptoms of cryptosporidiosis generally begin 2 to 10 days (average 7 days) after infection and last 1 to 2 weeks. The most common symptom of cryptosporidiosis is watery diarrhoea, but some people have no symptoms at all (CDC, 2024a).

Cryptosporidiosis is a disease that causes watery diarrhoea. It is caused by microscopic germs – parasites called Cryptosporidium. Both the parasite and the disease are commonly known as 'Crypto' (CDC, 2024). Although cryptosporidiosis can affect all people, some groups are likely to develop more serious illness. For people with weakened immune systems, symptoms can be severe and could lead to serious or life-threatening illness.

Cryptosporidiosis is endemic worldwide; the highest rates are found in low- and middle-income countries. An estimated 823,000 cryptosporidiosis cases occur in the United States each year, of which 9.9% are thought to be due to international travel. The highest US rates of reported cryptosporidiosis are in young children aged 1–4 years and in people aged 15–44 years, particularly females (likely caregivers changing diapers and helping with toileting). International travel is a risk factor for sporadic cryptosporidiosis in the United States (population attributable risk is 11%) and other high-income nations; few studies, however, have assessed the prevalence of cryptosporidiosis in travellers (CDC, 2024b). Symptoms of cryptosporidiosis generally begin two to ten days (average seven days) after becoming infected with the parasite. They include watery diarrhoea (the most common symptom), stomach cramps or pain, dehydration, nausea, vomiting, fever and weight loss. Some people can shed Cryptosporidiosis despite being asymptomatic (CDC, 2024).

Symptoms usually last about one to two weeks (with a range of a few days to a month or more) in persons with healthy immune systems. Occasionally, people may experience a recurrence of symptoms after a brief period of recovery before the illness ends. Symptoms can come and go for up to 30 days.

People with weakened immune systems who have severe cryptosporidiosis can develop chronic illness or even life-threatening problems with digesting or absorbing nutrients from food, as well as increasing weakness and loss of muscle (wasting). Examples of people with weakened immune systems include people infected with HIV; cancer or transplant patients who take drugs that weaken the immune system; people with inherited diseases that affect the immune system and the risk of developing severe disease depends on how weakened the immune system is (CDC, 2024). Recent evidence from regions with high HIV prevalence has shown cryptosporidiosis to be more common and responsible for a higher fraction of diarrhoea morbidity and mortality for young children than previously believed. Cryptosporidiosis has been associated with a relatively high case fatality and nutritional stunting (Peletz et al.,

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2013).
Animal
Cryptosporidium can infect a wide range of vertebrate hosts, including birds, reptiles, and mammals (CDC, 2024c). *Cryptosporidium parvum* infects mainly the gastrointestinal tract and is an important cause of diarrhoea in young, unweaned livestock. Mortality is generally low but severe outbreaks may occur occasionally. Weaned and adult animals do not normally exhibit signs of disease but can excrete oocysts that may contaminate the environment facilitating onward transmission. There is no commercially available vaccine for cryptosporidiosis (WOAH, 2022).

Metrics and numeric limits

In 2016, *Cryptosporidium* infection was the fifth leading diarrhoeal aetiology in children younger than 5 years, and acute infection caused more than 48,000 deaths and more than 4.2 million disability-adjusted life-years lost (Khalil et al., 2018).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of drivers, impacts, and risk management

Hazard Drivers: There is strong evidence linking transmission of *Cryptosporidium* with inadequate sanitation, unsafe drinking water, and poor hygiene. *Cryptosporidium* are major zoonotic waterborne pathogens with many documented drinking-water outbreaks (WHO, 2025).

Transmission is primarily by the faecal-oral route. *Cryptosporidium hominis* and *C. parvum* are the major human pathogenic species. Livestock (predominantly cattle and sheep), particularly young animals in the pre-weaning period, are important sources of zoonotic *C. parvum*. (WHO, 2025).

Cryptosporidium infection occurs worldwide; the resulting illness is characteristically prolonged, watery diarrhoea that is usually self-limiting. Malnourished young children and severely immunocompromised individuals may suffer chronic severe diarrhoea with significant loss of fluid and increased morbidity and mortality. *Cryptosporidium* is one of the major causes of morbidity and mortality from diarrhoeal disease in malnourished young children (WHO, 2025).

Cryptosporidium is a small protozoan parasite that infects the microvillous region of epithelial cells in the digestive and respiratory tract of vertebrates. It is an obligate intracellular parasite of man and other mammals, birds, reptiles and fish. It requires its host to multiply. Environmentally robust oocysts are shed by infected hosts into the environment. These oocysts can survive the adverse conditions in the environment for months until ingested by a new suitable host. In the new host, the life cycle starts again, and multiplication occurs, using the resources of the host (WHO, 2009).

Cryptosporidium outbreaks have been reported in hospitals, daycare centres, within households, among people eating the same food, among people pursuing recreational water activities (in lakes and swimming pools), and in municipalities with contaminated public water supplies. Water distribution systems are particularly vulnerable to contamination with *Cryptosporidium*, which can survive most disinfection procedures such as chlorination (ECDC, no date).

Impacts: The reported incidence of *Cryptosporidium* ranges from <1% in high-income countries up to 8% in low- and middle-income countries. In 2016, *Cryptosporidium* infection was the fifth leading diarrhoeal aetiology in children younger than 5 years, and acute infection caused more than 48,000 deaths and more than 4.2 million disability-adjusted life-years lost (Khalil et al., 2018).

Multi-hazard Context: Not Applicable.

Monitoring: The section and the table below offer an overview of monitoring for anthrax. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

1. Which institution(s) produce(s) Disaster Risk Data/Information?	WHO, Ministry of Health FAO Reference Centres, WOAH Reference Centres
2.a. How is the Hazard Monitored / Observed / Forecast?	WHO, Ministry of Health FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country's risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance

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system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date).

Risk Management: *Cryptosporidium* lives in the intestine of infected humans or animals. An infected person or animal sheds *Cryptosporidium* parasites in the stool. Millions of *Cryptosporidium* parasites can be released in a bowel movement from an infected human or animal. Shedding begins when the symptoms begin and can last for weeks after the symptoms (e.g., diarrhoea) disappear. People become infected after accidentally swallowing the parasite (CDC, 2024).

Cryptosporidium is transmitted via the faecal-oral route. Its low infectious dose, prolonged survival in moist environments, protracted communicability, and extreme chlorine tolerance make *Cryptosporidium* ideally suited for transmission through contaminated drinking or recreational water (e.g., swimming pools). Transmission also can occur through contact with faecally contaminated surfaces, by eating contaminated food, or through contact with infected animals (particularly pre-weaned bovine calves) or people (e.g., when providing direct care, during oral-anal sex).

Routine testing for ova and parasites does not typically include *Cryptosporidium*; specifically request testing for this organism when *Cryptosporidium* infection is suspected. New molecular enteric panel assays generally include *Cryptosporidium* as a target pathogenicity (CDC 2024b). Other diagnostic techniques include microscopy with direct fluorescent antibody (considered the gold standard), enzyme immunoassay kits, molecular assays, microscopy with modified acid-fast staining, and rapid immunochromatographic cartridge assays (CDC 2024b). Infections caused by different *Cryptosporidium* species and subtypes can differ clinically. Most *Cryptosporidium* species, all with multiple subtypes, are indistinguishable by traditional diagnostic tests (CDC 2024b).

Travelers can reduce their risk for cryptosporidiosis by carefully adhering to food and water precautions and using proper handwashing techniques. To protect themselves, swimmers should avoid ingesting recreational water. To protect others, people infected with cryptosporidiosis should not enter recreational water while ill with diarrhoea, and for the first 2 weeks after symptoms have completely resolved, because of prolonged excretion of infectious oocysts. Practising safer sex (i.e., reducing contact with faeces) can also decrease the risk of infection (CDC 2024b).

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Coordinating agency or organisation

World Health Organization, Food and Agriculture Organization of the United Nations (FAO).

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BI0112 / BIOLOGICAL / Infectious Diseases (Human and Animal)

zoonosis

Cysticercosis

Definition

Cysticercosis is a preventable infection in humans and pigs caused by the larval stages of the parasite *Taenia solium* (pork tapeworm). Human cysticercosis can result in devastating effects when the larvae are located in the central nervous system, resulting in neurocysticercosis which may cause convulsions and epileptic seizures and can be fatal. It is the main cause of preventable epilepsy where the parasite is present, and it is estimated to affect between 2.56 and 8.30 million people (adapted from WHO, 2024).

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WOAH. No date. Porcine cysticercosis. https://www.woah.org/en/disease/porcine-cysticercosis/ Accessed 26 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Cysticercus cellulosae Infection, Human Cysticercosis, Cysticercosis, neurocysticercosis (NCC), Porcine Cysticercosis, *Taenia solium*, Taenia solium Cysticercoses, Taeniasis, and pork tapeworm infection

Additional scientific description

Taenia solium is a zoonotic parasite whose life cycle involves both humans and pigs. The parasite, *Taenia solium,* causes three diseases: taeniasis in humans, cysticercosis in pigs and cysticercosis in humans. *T. solium* is included in the WHO portfolio of Neglected Tropical Diseases.

Human
Taeniasis in humans is acquired when people undercooked infected pork that contains *T. solium* larvae, which then develop into adult tapeworms in the small intestine. Taeniasis in humans is usually asymptomatic or characterized by mild/non-specific symptoms such as abdominal pain or diarrhoea. Symptom onset occurs when the tapeworms become fully developed in the intestine, usually approximately 8 weeks following ingestion. These symptoms may continue until the tapeworm dies following treatment, otherwise it may live for several years. Human tapeworm carriers excrete tapeworm eggs in their faeces and contaminate the environment when they defecate in open areas. Ingestion of the excreted tapeworm eggs from the environment causes human and porcine cysticercosis.
Human cysticercosis is transmitted through the ingestion of tapeworm eggs through the faecal oral route or contaminated food/water. The ingested eggs develop into larvae that encyst in the muscles, under the skin, eyes or in the central nervous system causing neurocysticercosis, which is the most serious disease caused by *T. solium.* Most neurocysticercosis is asymptomatic, however, the most common features are seizures, and it is the leading cause of preventable epilepsy worldwide. Cysts lodged in different parts of the brain give rise to unique clinical syndromes such as s focal epilepsy, epileptic seizures, hydrocephalus, chronic headaches, and symptoms associated with increased intracranial hypertension.

The incubation period prior to the appearance of clinical symptoms varies, and infected people may remain asymptomatic for many years.

The internationally recognized criteria for diagnosis of neurocysticercosis include a requirement for neuroimaging techniques, such as computerized tomography (CT) and/or magnetic resonance imaging (MRI), ideally supported by serology. These facilities are not available in all settings, especially in rural areas of low-income countries, making it difficult to identify and treat patients. Therefore, the prevalence of infection and disease, morbidity, and mortality are probably grossly underestimated. The management of neurocysticercosis may include anthelmintic, anti-inflammatory and antiepileptic drug (AED) treatments, and neurosurgery in some cases as detailed in the WHO guidelines on the management of cysticercosis (WHO, 2021).

Animal

Swine are the usual intermediate host for *T. solium* but humans, the usual definitive host, can serve as accidental intermediate hosts following ingestion of infectious eggs (CDC, 2019). Specific control measures in the pig population include the vaccination of pigs with the TSOL18 vaccine and the treatment with oxfendazole. Vaccination prevents the pigs from getting infected; oxfendazole cures the pigs already infected at the time of vaccination, and both can be given simultaneously (WHO, no date).

Metrics and numeric limits

T. solium is endemic in 51 countries, with a further 14 countries suspected endemic mostly in Africa, Asia and Latin America (WHO, 2022 b).

The total number of people with symptomatic or asymptomatic neurocysticercosis is estimated to be 2.56-8.30 million. The greatest burden of *T. solium*-induced disease is due to neurocysticercosis, which is estimated to contribute to approximately 30% of epilepsy cases in areas where the disease is endemic. However, in specific communities, it can be up to 70%. Approximately 80% of people with epilepsy live in low- and middle-income countries and most do not receive appropriate treatment (WHO, 2022b).

In Latin America, it is estimated that in 2010 there were 30 859 cases of neurocysticercosis (NCC) and 960 deaths, causing 180 829 years of disabilities-adjusted life (DALYs) (PAHO, no date)

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, outcomes and risk management

Hazard Drivers: Key drivers for cysticercosis include the number of backyard pigs and the prevalence of open rural defecation.

Taeniasis is the intestinal infection of the adult tapeworm. When left untreated, a more serious condition known as cysticercosis develops as *T. solium* larvae invade body tissues. When larvae build up in the central nervous system, muscles, skin and eyes, it leads to neurocysticercosis – the most severe form of the disease and a common cause of seizures worldwide (WHO, 2018)

T. solium taeniasis is acquired by humans through the ingestion of the parasite's larval cysts (cysticerci) in undercooked and infected pork. Human tapeworm carriers excrete tapeworm eggs in their faeces and contaminate the environment when they defecate in open areas. Humans can also become infected with *T. solium* eggs due to poor hygiene (via the faecal-oral route) or ingesting contaminated food or water (WHO, 2022a).

Ingested *T. solium* eggs develop into larvae (called cysticerci) in various organs of the human body. When they enter the central nervous system, they can cause neurological symptoms (neurocysticercosis), including epileptic seizures. *T. solium* is the cause of 30% of epilepsy cases in many endemic areas where people and roaming pigs live in close proximity. In high-risk communities it can be associated with as many as 70% of epilepsy cases (WHO, 2022a).

Impacts: *T. solium* produces a significant societal impact. Neurocysticercosis carries a significant economic burden, increasing poverty through high treatment costs for patients and their families and the healthcare system. This is compounded by the economic losses associated with porcine cysticercosis through loss of value from infected pigs, Furthermore, many patients specifically female patients face discrimination and stigma due to the symptoms of epilepsy (which is associated with witchcraft), increasing inequalities.

Multi-hazard Context: More than 80% of the world's 50 million people who are affected by epilepsy live in low and lower-middle-income countries (WHO, 2022 a). Neurocysticercosis is the most frequent preventable cause of epilepsy worldwide and is estimated to cause 30% of all epilepsy cases in countries where the parasite is endemic. In specific communities, the association between neurocysticercosis and epilepsy can be up to 70%. In poor remote settings where the disease is present, epilepsy is difficult to diagnose and treat, and causes major stigma, especially in girls and women (WHO, 2022a)

Cysticercosis mainly affects the health and livelihoods of subsistence farming communities in developing countries of Africa, Asia and Latin America. It also reduces the market value of pigs and makes pork unsafe to eat (WHO, 2022a)

In the WHO *Taenia solium* endemicity map - 2022 update, it was reported that of the 196 countries and territories assessed, 51 were

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classified as endemic for T. solium, 14 as suspected endemic, 21 as having few pigs exposed to risk factors and 55 as not endemic. There was insufficient data for 59 countries and no data or possible transmission in some communities in 14 countries WHO, 2022b).

Monitoring: The table below offers an overview of monitoring for cysticercosis. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	WHO, Ministry of Health WOAH Reference Centres
How is the Hazard Observed/Monitored/Forecast?	WHO, Ministry of Health FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

Robust surveillance data is fundamental to assess disease burden, take action and evaluate progress. As for other neglected diseases, data is especially scarce. WHO is active in countering this situation by collecting and mapping data on *T. solium* distribution and risk factors associated with the occurrence of the parasite, such as information on pig keeping, food safety and sanitation. This information has been incorporated into the WHO Global Health Observatory (WHO, 2022a)

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date).

Risk Management: *T. solium* cysticercosis remains a neglected disease because of a lack of general awareness, lack of information on disease burden, a paucity of validated tools for field diagnosis, lack of resources for control and treatment, poor access to neuroimaging and neurological care and hesitation to invest in zoonotic neglected tropical diseases.

Human
The control and elimination of *T. solium* are hindered by many factors, including the lack of reliable epidemiological data on infections in people and pigs. Appropriate surveillance and point-of-care diagnostic tools would enable identification and targeted interventions in high-risk communities. Key preventative measures include preventive chemotherapy for taeniasis, and a One Health approach involving vaccination and anthelmintic treatment of pigs to prevent infection with *T. solium cysticerci*. Health promotion and awareness of the community are necessary to support those interventions. Other interventions require a longer-term approach such as improved pig management practices to prevent exposure of pigs to human faeces; improved sanitation to prevent contact between pigs or humans and *T. solium* eggs in human faeces and in the environment; meat inspection and sufficient cooking of pork to reduce the risk of humans becoming infected and health education to promote hand hygiene, food safety, sanitation and pig management (WHO, 2023).
Animal
Prevention and control in animals include: Improved pig-farming practices; Vaccination of pigs with TSOL18; Treatment of pigs with oxfendazole; Meat inspection, meat processing (freezing) (FAO, OIE & WHO, 2021).

Preliminary – Corrections Pending

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Coordinating agency or organisation

World Health Organization (Taeniasis, Human Cysticercosis), World Organization for Animal Health (Porcine Cysticercosis), Food and Agriculture Organization of the United Nations (FAO).

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BI0113 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Zoonotic Diseases

Definition

Zoonotic diseases, or zoonoses, are diseases shared between animals – including livestock, wildlife, and pets – and people. They can pose serious risks to both animal and human health, and may have far-reaching impacts on economies and livelihoods and represent a major public health problem. Zoonotic diseases are commonly spread at the human-animal-environment interface – where people and animals interact with each other in their shared environment (adapted from WHO, FAO, WOAH, 2019 & WHO, 2020).

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Annotations

Synonyms

Zoonoses.

Additional scientific description

A zoonotic disease is any disease that is naturally transmissible from vertebrate animals to humans. Animals therefore play an essential role in maintaining zoonotic infections in nature. Zoonoses may be bacterial, viral, or parasitic, or may involve unconventional agents. As well as being a problem for public health many of the major zoonotic diseases prevent the efficient production of food of animal origin and create obstacles to international trade in animal products (WHO, 2020).

Zoonotic diseases can be transmitted to humans in a number of different ways which vary depending on the specific disease. In addition to direct contact with animals, they may be transmitted by: transmission from person to person; inhalation of spores or contaminated dust; consumption of unpasteurised dairy products or contaminated food; consumption of contaminated water; skin exposure to spores or contaminated water; and animal or insect bites/scratches (CDC, 2024).

Some zoonotic diseases begin as a zoonosis but later mutate into human-only strains, for example, human immunodeficiency virus (HIV). Others can cause recurring disease outbreaks, such as Ebola virus disease and salmonellosis (WHO, FAO & WOAH, 2019).

Zoonotic diseases comprise a large percentage of all newly identified infectious diseases as well as many existing ones. There are over 200 known types of zoonotic disease (WHO, 2020). It is estimated that over 75% of emerging infectious human diseases are zoonotic, giving animals a major role as reservoirs in the dynamics of these diseases (WOAH, 2024).

The health of humans, animals, and ecosystems are closely interlinked. Changes in these relationships can increase the risk of new human and animal diseases developing and spreading. The close links between human, animal and environmental health demand close collaboration, communication and coordination between the relevant sectors. One Health is an approach to optimize the health of humans, animals and ecosystems by integrating these fields, rather than keeping them separate (WHO, 2023).

Examples of major zoonosis in HIPs: Anthrax (BI0201), COVID-19 (SARS-CoV-2) (BI0205), Avian Influenza (BI0245), Crimean-Congo Haemorrhagic Fever (BI0206), Ebola (BI0209), Middle East Respiratory Syndrome (MERS) (BI0223), Mpox (BI0224), Rabies (BI0232), Severe Acute Respiratory Syndrome (SARS) (BI0236), Brucellosis (BI0202), New World Screwworm (NWS) (BI0309), Rift Valley Fever (BI0311), Trypanosomosis (BI0238).

Metrics and numeric limits

Since 2003, the world has seen over 15 million human deaths and US$ 4 trillion in economic losses due to disease and pandemics, as well as immense losses from food and water safety hazards, which are One Health related health threats (WHO, 2023).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Quadripartite Memorandum of Understanding (MoU) signed for a new era of One Health collaboration 2022 (FAO, OiE, UNEP & WHO, 2022)

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: A zoonosis is an infectious disease that has jumped from a non-human animal to humans. Zoonotic pathogens may be bacterial, viral or parasitic, or may involve unconventional agents and can spread to humans through direct contact or through food, water or the environment. They represent a major public health problem around the world due to our close relationship with animals in agriculture, as companions and in the natural environment. Zoonoses can also cause disruptions in the production and trade of animal products for food and other uses (WHO, 2020).

Zoonoses comprise a large percentage of all newly identified infectious diseases as well as many existing ones. Some diseases, such as HIV, begin as a zoonosis but later mutate into human-only strains. Other zoonoses can cause recurring disease outbreaks, such as Ebola virus disease and salmonellosis. Still others, such as the novel coronavirus that causes COVID-19, have the potential to cause global pandemics (WHO, 2020).

Impacts: Antimicrobial resistance is a complicating factor in the control and prevention of zoonoses. The use of antibiotics in animals raised for food is widespread and increases the potential for drug-resistant strains of zoonotic pathogens capable of spreading quickly in animal and human populations (WHO, 2020).

Markets selling the meat or by-products of wild animals are particularly high risk due to the large number of new or undocumented pathogens known to exist in some wild animal populations (WHO, 2020).

Multi-hazard Context: Not Applicable.

Monitoring: The section and the table below offer an overview of monitoring for zoonotic diseases. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	WHO, Ministry of Health, FAO Reference Centres, WOAH Reference Centres
How is the Hazard Observed/Monitored/Forecast?	WHO, Ministry of Health FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a disaster from natural hazards. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023).

Risk Management: Taking a multisectoral, One Health approach is necessary to address complex health threats at the human-animal-environment interface, such as rabies, zoonotic influenza, anthrax, and Rift Valley fever. Such zoonotic diseases continue to have major impacts on health, livelihoods, and economies, and cannot be effectively addressed by one sector alone (WHO, FAO & WOAH, 2019).

The World Health Organization (WHO) in partnership with the United Nations Food and Agricultural Organization (FAO) and World Organisation for Animal Health (OIE), leads the development of global norms and standards for zoonotic diseases, as

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well as technical work on pathogen detection, risk assessment and management (WHO, FAO & OIE, 2019).

On 17 March 2022. the four international agencies, the Food and Agriculture Organization of the United Nations (FAO), the World Organisation for Animal Health (OIE), the UN Environment Programme (UNEP) and the World Health Organization (WHO), have signed a groundbreaking agreement to strengthen cooperation to sustainably balance and optimize the health of humans, animals, plants and the environment. The new Quadripartite MoU provides a legal and formal framework for the four organizations to tackle the challenges at the human, animal, plant and ecosystem interface using a more integrated and coordinated approach. This framework will also contribute to reinforcing national and regional health systems and services (FAO, OiE, UNEP & WHO, 2022)

One Health is an integrated, unifying approach to balance and optimize the health of people, animals and ecosystems. It uses the close, interdependent links among these fields to create new surveillance and disease control methods. For example, the way land is used can impact the number of malaria cases. Weather patterns and human-built water controls can affect diseases like dengue. Trade in live, wild animals can increase the likelihood of infectious diseases jumping over to people (called disease spillover).

Gaps in One Health knowledge, prevention and integrated approaches were seen as key drivers of the pandemic. By addressing the linkages between human, animal and environmental health, One Health is seen as a transformative approach to improved global health. One Health applies to a range of issues, including:

- antimicrobial resistance (AMR), which happens when germs like bacteria and parasites develop the ability to defeat the drugs designed to kill them and continue growing and spreading;
- zoonotic diseases, which are infectious diseases that are caused by germs that spread between animals and people, such as Ebola, avian influenza, rabies, etc.;
- vector-borne diseases, which affect people who get bitten by a vector (mosquitoes, ticks, lice and fleas) and include dengue fever, West Nile virus, Lyme disease and malaria;
- food safety and foodborne diseases, caused by contamination of food and occur at any stage of the food production, delivery and consumption chain, such as norovirus, salmonella, listeria, etc.; and
- environmental health, such as water pollution, air pollution and climate change.

Collaboration across sectors and disciplines through a One Health approach is a vital solution for addressing the complex health challenges facing our society. To prevent, detect and respond to emerging health challenges, all relevant sectors must collaborate in an integrated manner to achieve together what no sector can achieve alone.

Prevention methods for zoonotic diseases differ for each pathogen; however, several practices are recognised as effective in reducing risk at the community and personal levels including safe animal husbandry, increased hygiene measures and standards for clean drinking water and waste removal. Some zoonoses, such as rabies, are 100% preventable through vaccination and other methods (WHO, 2020).

As part of the One Health approach, the WHO collaborates with the FA) and the WOAH on the Global Early Warning System for Major Animal Diseases GLEWS). This joint system builds on the added value of combining and coordinating alert mechanisms of the three agencies to assist in early warning, prevention and control of animal disease threats, including zoonoses, through data sharing and risk assessment (WHO, 2020)

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Coordinating agency or organisation

United Nations Food and Agricultural Organization (FAO), World Organisation for Animal Health (OIE), World Health Organization (WHO).

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BI0201 / BIOLOGICAL / Infectious Diseases (Human and Animal)

zoonosis

Anthrax

Definition

Anthrax is a disease caused by the spore-forming bacteria *Bacillus anthracis*. Anthrax is primarily a disease of herbivorous animals, although all mammals, including humans, can contract it. In humans, anthrax manifests itself in three distinct patterns (cutaneous, gastrointestinal, inhalational) (adapted from WHO, FAO & OIE, 2008; CDC, 2020).

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Annotations

Synonym

Fièvre charbonneuse, Charbon bactéridien (fr), Carbunco bacteridiano (es),

Additional scientific description

Human

• The disease is generally regarded as being non-contagious. However, potentially it can be transmitted via direct contact with infected sores. When anthrax spores are ingested, inhaled or enter the body through skin abrasions or cuts, they can germinate, multiply and produce toxins.
• More than 95% of human anthrax cases take the cutaneous form and result from handling infected carcasses or hides, hair, meat or bones from such carcasses.
• Human case rates for anthrax are highest in Africa, the Middle East and central and southern Asia.
• Anthrax can also be contracted in laboratory accidents and by heroin-injecting drug-users through injection of contaminated heroin.
• There are three forms of anthrax, and all forms are potentially fatal if untreated, but the cutaneous form is more often self-limiting.
• Cutaneous anthrax
  ○ most common form (more than 95% of the cases), usually contracted when a person with a break in their skin, such as a cut or abrasion, comes into direct contact with anthrax spores generally from handling infected carcasses or hides, hair, meat or bones from such carcasses.
  ○ the resulting itchy bump rapidly develops into a black sore. Some people then develop headaches, muscle aches, fever and vomiting.
• Gastrointestinal anthrax
  ○ caught from eating meat from an infected animal.

- It causes initial symptoms similar to food poisoning, but these can worsen to produce severe abdominal pain, vomiting of blood and severe diarrhoea.

- Inhalational or pulmonary anthrax
  - the most severe, and rarest, form of human anthrax caused when a person is directly exposed to a large number of anthrax spores suspended in the air and breathes them in.
  - the first symptoms are similar to those of a common cold, but this can rapidly progress to severe breathing difficulties and shock.
- All three forms (cutaneous, gastrointestinal, inhalational) are potentially fatal if untreated, but the cutaneous form is more often self-limiting. Data from pre-antibiotic and vaccine days indicate that 10%–40% of untreated cutaneous cases may be expected to result in death with some geographical and temporal variations (WHO, FAO & OIE, 2008).
- Bacillus anthracis has always been high on the list of potential agents with respect to biological warfare and bioterrorism. It has been used in that context on at least two occasions, prepared for use on several other occasions and been the named agent in many threats and hoaxes (WHO, FAO & OIE, 2008).
- Humans generally acquire the disease directly or indirectly from infected animals, or occupational exposure to infected or contaminated animal products. Control in livestock is therefore the key to reduced incidence in humans.

Animal

- Anthrax is primarily a disease of herbivores (WHO, FAO & OIE, 2008). Anthrax occurs on all continents and commonly causes high mortality, primarily in domestic and wild herbivores as well as most mammals and several bird species (WOAH, no date). Anthrax is preventable through control measures, including vaccination (Fasanella et al., 2021). Each country has a list of approved vaccines and antibiotics for use. Contact national veterinary services to learn what is allowed in the country before purchasing.
- Anthrax is most common in agricultural regions with neutral or alkaline, calcareous soils. Bacillus anthracis forms highly resistant spores that can persist in the environment for decades and infect grazing animals.
- Anthrax continues to be reported from many countries in domesticated and wildlife.
- Anthrax outbreak in an enzootic area follows a prolonged hot dry spell, which in turn was preceded by heavy rains or flooding, or with rain ending a period of drought. The water allows anthrax spores to germinate.
- In the livestock sector, where people become infected by handling animals or animal products that contain spores, people often develop skin infections. This can happen to veterinarians, agricultural workers, livestock producers or those employed in the processing of sick animals, bones, hides, wool and other animal products.
- Anthrax develops without apparent clinical signs, with sudden death due to acute or hyperacute septicaemia and leakage of uncoagulated blood from natural openings.
- In cattle, anthrax often occurs as an acute febrile disease. A steep rise in temperature is a typical sign. If no treatment is given, death usually occurs in 2–3 days. The urine may be blood-stained, and blood may exude from the rectum and other natural openings.

Metrics and numeric limits

Human

- Infectious doses, which have not been established for humans, and the severity of the resulting infection clearly depend on several factors such as route of infection, nutritional and other states of health on the part of the infected person and probably on the relative virulence of the infecting strain.
- For the purpose of risk assessments, dependency on information from animal tests is unavoidable (WHO, 1998).

Animal

- N/A

Key relevant UN convention / multilateral treaty

Codex Alimentarius (FAO and WHO, no date).

International Health Regulations (2005), 3rd ed (WHO, 2016).

WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) (WTO, no date).

United Nations. 2023. Recommendations on the Transport of Dangerous Goods - UN Model Regulations. https://unece.org/transport/dangerous-goods/un-model-regulations-rev-23 Accessed 1 January 2025.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Anthrax has been classified as non-industrial and industrial anthrax, reflecting the occupation of the individual

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led to exposure; non-industrial anthrax, which occurs in farmers, butchers, knackers, veterinarians and so on, and industrial anthrax, which occurs in those employed in the processing of bones, hides, wool and other animal products. (WHO, 1998).

Anthrax is primarily a disease of herbivores. Typically, an outbreak in an enzootic area follows a prolonged hot dry spell, which in turn is preceded by heavy rains or flooding, or with rain ending a period of drought (WHO, FAO & OIE, 2008).

Impacts: Anthrax is a fatal disease in humans and animals. Anthrax is an infection caused by the spore-forming bacteria called Bacillus anthracis. It is a zoonosis (disease transmissible from animals to humans) that typically affects ruminants (such as cows, sheep, and goats). The bacteria produce extremely potent toxins which are responsible for the symptoms, causing a high lethality rate. Humans can catch the disease from infected animals or through contaminated animal products (EHO, 2016 a).

Multi-hazard Context: Bacillus anthracis has always been high on the list of potential agents with respect to biological warfare and bioterrorism. It has been used in that context on at least two occasions, prepared for use on several other occasions and been the named agent in threats and hoaxes (WHO, FAO & OIE, 2008).

Monitoring: The section and the table below offer an overview of monitoring for anthrax. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	WHO, Ministry of Health FAO Reference Centres, WOAH Reference Centres
How is the Hazard Observed/Monitored/Forecast?	WHO, Ministry of Health FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date).

Risk Management: Preventing the disease in animals will protect human health. Anthrax vaccines for livestock and humans exist. Anthrax provides a good platform for a 'One Health' approach which can be operationalised through locally adapted approaches for prevention and control. The control of anthrax among humans depends on the integration of veterinary and human health surveillance and control programmes. Routine cross-notification between the veterinary and human health surveillance systems and close collaboration between the two health sectors is particularly important during epidemiological and outbreak investigations (WHO 1998; 2024).

The Food and Agriculture Organization of the United Nations provides information on anthrax outbreaks via its guidance for improved prevention, control and heightened awareness. These efforts should be supported by enhanced intersectoral collaboration and coordination between the veterinary and medical authorities, particularly at the field level, for information and report exchange, integration of surveillance data, joint case investigations, coordination of community awareness messaging and implementation, and effective delivery of vaccination campaigns (FAO, 2018).

In the World Organisation for Animal Health (WOAH, formerly) Terrestrial Animal Health Code chapter on anthrax, it is reported that there is no evidence that anthrax is transmitted by animals before the onset of clinical and pathological signs. It provides guidance on early detection of outbreaks, quarantine of affected premises, destruction of diseased animals and fomites, and implementation of appropriate sanitary procedures at abattoirs and dairy factories will ensure the safety of products of animal origin intended for human consumption (WOAH, 2024)

Human
• Hospitalization is required for all human cases of anthrax. Individuals potentially exposed to anthrax spores may be provided with prophylactic treatment. Anthrax responds well to antibiotics.

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- Human vaccines are in limited supply and used primarily for protection of selected individuals with possible occupational exposure to anthrax (WHO, 2016a).
- Bacillus anthracis has always been high on the list of potential agents with respect to biological warfare and bioterrorism.
- The high-risk groups from anthrax include
  - Working in abattoirs
  - Working in veterinary medicine (dealing with livestock)
  - Handlers of animal skin, wool or dairy products in high-incidence areas for anthrax
  - Laboratory workers dealing with Anthrax
  - Injection drug users (heroin)

Animal

- When anthrax is suspected in livestock or animals, immediately contact the Veterinary Service. Do not move or open the carcasses and do not allow people to take meat.
- Control measures include the correct disposal of carcasses, disinfection and decontamination of contaminated materials, and decontamination of the environment.
- Anthrax-specific control procedures on carcasses disposal are necessary to contain the disease and prevent its spread. Typically, the carcasses will be burnt or deep-buried at the death site to prevent the spreading of spores.
- When buried, need to ensure that it is inaccessible to other animals, particularly scavengers, or people. Hazard signs should be posted around sites.
- Because the spores survive in the soil for a long time, dredging or digging of an anthrax burial site may result in a new anthrax outbreak.
- In villages, people contract gastrointestinal anthrax when they steal meat from buried anthrax-infected carcasses and eat/share. Hence, timely Risk communication and community engagement (RCCE) is crucial.

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Coordinating agency or organisation

Food and Agriculture Organization of the United Nations (FAO), World Health Organization (WHO), World Organisation for Animal Health (WOAH).

Preliminary – Corrections Pending

BI0202 / BIOLOGICAL / Infectious Diseases (Human and Animal)

zoonosis

Brucellosis (Human and Animal)

Definition

Brucellosis is a bacterial disease caused by various Brucella species, which mainly infect cattle, swine, goats, sheep and dogs. Humans generally acquire the disease through direct contact with infected animals (WHO, 2020).

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Annotations

Synonyms

Undulant fever, Contagious abortion, Malta fever, Mediterranean fever.

Additional scientific description

Human

Brucellosis is one of the most widespread zoonoses transmitted by animals and in endemic areas, human brucellosis has serious public health consequences. The expansion of animal industries and urbanisation, and the lack of hygienic measures in animal husbandry and food handling, partly account for brucellosis remaining a public health hazard (WHO, 2020).

Brucellosis is mainly caused by Brucella abortus, biovars 1-6, 9; *B. melitensis*, biovars 1-6; *B. suis*, biovars 1-5; and *B. canis* (WHO, 2001). Worldwide, *B. melitensis* is the most prevalent species causing human brucellosis, owing in part to difficulties in immunising free-ranging goats and sheep (WHO, 2020).

Although there has been great progress in controlling the disease in many countries, there still remain regions where the infection persists in domestic animals and, consequently, transmission to the human population frequently occurs. It is an important human disease in many parts of the world especially in the Mediterranean countries of Europe, north and east Africa, the Middle East, south and central Asia and Central and South America and yet it is often unrecognized and frequently goes unreported. There are only a few countries in the world that are officially free of the disease although cases still occur in people returning from endemic countries (FAO, OIE & WHO, 2006).

Brucellosis typically causes flu-like symptoms, including fever, weakness, malaise and weight loss. However, the disease may present in many atypical forms and which, in the absence of specific treatment, may persist for weeks or months. In many patients the symptoms are mild and, therefore, the diagnosis may not be considered. The incubation period of the disease can be highly variable, ranging from 1 week to 2 months, but usually 2 to 4 weeks (FAO, OIE & WHO, 2006; WHO, 2020). Human-to-human transmission is very rare (WHO, 2020).

Animal

Brucellosis is a bacterial disease of livestock with significant economic impact. In endemic areas, vaccination is often used to reduce the incidence of infection. Several vaccines are available. Most countries maintain a list of approved veterinary vaccines for use. For specific regulations, consult the country's veterinary authorities (Blasco et al., 2021; WOAH, no date).

Brucellosis affects cattle, swine, sheep and goats, camels, equines, and dogs. It may also infect other ruminants, some marine mammals and humans. The disease in animals is characterized by abortions or reproductive failure. While animals typically recover following the initial abortion, they may continue to shed the bacteria. The poor reproductive performance results in huge economic losses to dairy, sheep, goat and pig farmers. Brucellosis is typically spread when the animal aborts or gives birth. High levels of bacteria are found in the birth fluids of an infected animal. The bacteria can survive outside the animal in the environment for several months, particularly in cool moist conditions. They remain infectious to other animals which become infected by ingesting the bacteria. The bacteria also colonise the udder and contaminate the milk. Brucellosis is also an important disease in wildlife, infecting feral pigs, bison, elk and European hares (Wernery, 2014; WOAH, no date).

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Brucellosis in cattle (*B. abortus*), sheep and goats (*B. melitensis*), and swine (*B. suis*) are diseases listed in the World Organisation for Animal Health (WOAH) Terrestrial Animal Health Code (WOAH, no date).

Metrics and numeric limits

Disability adjusted life years (DALYs) are used as a measure to evaluate the impact of the morbidity caused by brucellosis in humans.

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016). Codex Alimentarius (FAO, no date).

WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) (WTO, 1994).

Collaboration between the World Trade Organization (WTO) and the World Organization for Animal Health (OIE) concerning the use of international standards in the context of the SPS Agreement (WTO, 2007). United Nations. 2023. UN Recommendations on the Transport of Dangerous Goods - UN Model Regulations Model Regulations. https://unece.org/transport/dangerous-goods/un-model-regulations-rev-23.

Examples of hazard drivers, impacts, and risk management

Human
Hazard Drivers: introduction of sub-clinically infected animals. The disease is also considered an occupational hazard for people who work in the livestock sector. People who work with animals and are in contact with blood, placenta, foetuses and uterine secretions have an increased risk of contracting the disease. This method of transmission primarily affects farmers, butchers, hunters, veterinarians and laboratory personnel (WHO, 2020). **Impacts**: Brucellosis generates disease in humans after consuming unheated dairy products (e.g., raw milk); and trade implications. These may involve substantial economic losses, including loss of income and manpower, medical care costs, and loss of food due to inadequacy of processing or spoilage.
Animal
Hazard Drivers: Not Applicable **Impacts**: huge economic losses to dairy, sheep, goat and pig farmers (WOAH, no date).

Multi-hazard Context: Brucellosis is found globally and is a reportable disease in most countries. It affects people of all ages and both sexes. In the general population, most cases are caused through direct contact with infected animals, by eating or drinking contaminated animal products or by inhaling airborne agents. Most cases are caused by ingesting unpasteurized milk or cheese from infected goats or sheep (WHO, 2020).

Monitoring: The table below offers an overview of monitoring for brucellosis. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Ministry of Health, Ministry of Agriculture, Ministry of Livestock, WHO, FAO Reference Centres, WOAH Reference Centres
How is the Hazard Observed/Monitored/Forecast?	Through its global early warning system, FAO has been supporting Members with risk monitoring, assessment and forecasting for animal health threats to enhance preparedness and response to animal health threats: • The Global Animal Disease Information System, EMPRES-i+, plays a crucial role in supporting countries with early warning and early detection of animal disease outbreaks. By providing a comprehensive platform for real-time disease tracking, EMPRES-i+, enables to monitor and analyse animal health threats effectively, collaborating closely with countries and regions on disease information sharing. This supports the dissemination of risk assessments and alerts for evidence-based decision-making. • FAO develops and maintains decision support tools that provide risk maps of existing and predicted risks of animal disease emergence, as well as other threats to the agri-food chain. • Additionally, FAO collaborates closely with international organizations like WHO and WOAH to verify disease information through integrated mechanisms such as the Epidemic Intelligence from Open Sources (EIOS), and the Global Early Warning System (GLEWS+), and through the World Animal Health Information System (WAHIS) for WOAH-listed diseases. These collaborations allow for the dissemination of early warning alerts and risk assessments to Members, to enable timely

Preliminary – Corrections Pending

	responses to potential outbreaks. FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country's risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023)

Risk Management: Control activities must be coordinated and shared between both public health and animal health sectors. Administrative arrangements between the two sectors must facilitate immediate cross-notification of cases, as well as joint investigations and control. Control programmes must be promoted in goat-raising areas (FAO, OIE & WHO, 2006).

Equally important, complementary control of animal and human brucellosis activities on the ground at the community level, where local veterinary and public health services interact and collaborate, is key to ensuring the application of adapted approaches for improving surveillance, enhancing community awareness, promoting milk pasteurisation and hygiene practices and delivering effective vaccination campaigns (FAO, 2014).

Guidance on brucellosis surveillance and standards is available from the Food and Agriculture Organization of the United Nations (FAO), the World Health Organization (WHO), the World Organisation for Animal Health (WOAH), and the United States Centres for Disease Control and Prevention (CDC).

The FAO has produced guidelines for coordinated human and animal brucellosis surveillance. The purpose of these general guidelines on surveillance in both human and animal populations is to provide a set of principles and techniques that can be used to develop and monitor new or existing brucellosis control programmes. The guidelines can also help in assessing the effectiveness of regulatory and advisory measures designed to safeguard public health (FAO, 2003).

The WHO provides technical advice to member states through the provision of standards, information and guidance for the management of brucellosis in humans and animals. The WHO works to support the coordination and sharing of information between the public health and animal health sectors. In collaboration with the FAO, the OIE and the Mediterranean Zoonoses Control Programme (MZCP), the WHO supports countries in the prevention and management of the disease through the Global Early Warning System for Major Animal Diseases (GLEWS) (WHO, 2020).

The OIE Terrestrial Animal Health Code provides guidance on infection with *Brucella abortus*, *B. melitensis* and *B. suis*, specifically Article 8.4 on the mitigation of the risk of spread of, and the risk to human health from, Brucella abortus, *B. melitensis* and *B. suis* in animals (OIE, 2019).

The CDC Brucellosis Reference Guide: Exposures, Testing, and Prevention is an example of a country approach. This guide includes the Brucella species as one of the biological agents and toxins that may pose a severe threat to public health, stating that the Brucella species are easily aerosolised and have a low infectious dose, cited at levels of between 10 and 100 microorganisms (CDC, 2017).

Human
Risk Management: Prevention of brucellosis is based on surveillance and the prevention of risk factors. The most effective prevention strategy is the elimination of infection in animals. In countries where eradication in animals through vaccination or elimination of infected animals is not feasible, prevention of human infection is primarily based on raising awareness, food-safety measures, occupational hygiene and laboratory safety. (WHO, 2020). Pasteurization of milk for direct consumption and for creating derivatives such as cheese is an important step in preventing transmission from animals to humans. Education campaigns about avoiding unpasteurized milk products can be effective, as well as policies on its sale (WHO, 2020). Risk management includes movement control and treatment with antimicrobials. It also involves routine surveillance, particularly among high-risk groups (farmers, shepherds, workers in slaughterhouses, butchers, veterinarians, and laboratory personnel). Another element of risk management is the mandatory early case-based reporting by health care providers or laboratories to upper levels of the public health sector as well as to the appropriate level of the animal health sector. In endemic countries where investigation of all reported cases may not be feasible, a representative proportion of reported cases should be investigated routinely.
Animal
Risk Management: Movement control; tracing back/forward of infected animals, depopulation of infected herds; vaccination of animals. Vaccination of cattle, goats and sheep is recommended in enzootic areas with high prevalence rates. Serological or other

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testing and culling can also be effective in areas with low prevalence. Abortion of affected animals is also a risk reduction approach. Public health education should be included among the essential activities to be performed within the framework of brucellosis control programmes or even as an independent activity (FAO, OIE and WHO, 2006).

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Coordinating agency or organisation

Food and Agriculture Organization of the United Nations, World Health Organization, World Organisation for Animal Health.

Preliminary – Corrections Pending

BI0203 / BIOLOGICAL / Infectious Diseases (Human)

Chikungunya

Definition

Chikungunya is a mosquito-borne viral infection caused by the chikungunya virus. It causes fever and severe arthralgia (joint pain) which is often debilitating. The disease can be endemic and epidemic in countries (WHO, 2025).

Reference

WHO, 2025. Chikungunya. World Health Organization (WHO). www.who.int/news-room/fact-sheets/detail/chikungunya Accessed 25 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Chikungunya disease, Chikungunya virus, CHIKV.

Additional scientific description

Chikungunya is a mosquito-borne viral disease first described during an outbreak in southern Tanzania in 1952. It is an RNA virus that belongs to the Alphavirus genus of the family Togaviridae. The name 'chikungunya' derives from a word in the Kimakonde language, meaning 'to become contorted', and describes the stooped appearance of sufferers with joint pain (arthralgia) (WHO, 2025).

Chikungunya virus is transmitted between humans through the bites of infected mosquitoes – mainly of the *Aedes aegypti* and *A. albopictus* species. Both species can also transmit other mosquito-borne viruses, including dengue and Zika fever viruses. In symptomatic patients, chikungunya disease onset is typically 4–8 days (range 2–12 days) after the bite of an infected mosquito. It is characterized by an abrupt onset of fever, frequently accompanied by severe joint pain. The joint pain is often debilitating and usually lasts for a few days but may be prolonged, lasting for weeks, months or even years. Other common signs and symptoms include joint swelling, muscle pain, headache, nausea, fatigue and rash. Since these symptoms overlap with other infections, including those with dengue and Zika viruses, cases can be misdiagnosed. In the absence of significant joint pain, symptoms in infected individuals are usually mild and the infection may go unrecognized (WHO, 2025).

Laboratory diagnosis is via serological and/or virological testing. Serological testing may confirm the presence of anti-chikungunya antibodies. Immunoglobulin M (IgM) antibody levels are highest three to five weeks after onset of symptoms. Virological testing may isolate the virus itself and should be performed on samples collected during the first week after the onset of symptoms (WHO, 2025).

Metrics and numeric limits

Chikungunya has been identified in over 110 countries in Asia, Africa, Europe and the Americas (WHO, 2025).

The European Centre for Disease Prevention and Control (ECDC) has published case classifications for outbreak management, epidemiological surveillance, and reporting (ECDC, 2018).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: The proximity of mosquito vector breeding sites to human habitation is a significant risk factor for chikungunya as well as for other diseases that Aedes mosquito species transmit. At present, the main method to control or prevent the transmission of chikungunya virus is to combat the mosquito vectors. Prevention and control rely heavily on

reducing the number of natural and artificial water-filled container habitats that support the breeding of mosquitoes. This requires mobilization of affected and at-risk communities, to empty and clean containers that contain water on a weekly basis to inhibit mosquito breeding and the subsequent production of adults. Sustained community efforts to reduce mosquito breeding can be an effective tool to reduce vector populations (WHO, 2025).

Impacts: Most patients recover fully from the infection; however, occasional cases of eye, heart, and neurological complications have been reported with chikungunya infections. Patients at extremes of the age spectrum are at higher risk for severe disease. Newborns infected during delivery and older people with underlying medical conditions may become severely ill and chikungunya infection can increase the risk of death (WHO, 2025).

Multi-hazard Context: Chikungunya vectors are bloodsucking insects, which ingest disease-producing microorganisms during a blood meal from an infected host (human or animal) and later transmit it into a new host, after the pathogen has replicated. Often, once a vector becomes infectious, they are capable of transmitting the pathogen for the rest of its life during each subsequent bite/blood meal (WHO, 2020).

Monitoring: WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a disaster from natural hazards. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023).

WHO also supports countries to conduct surveillance and control of arboviruses through the implementation of the Global Arbovirus Initiative. Launched in 2022, the Global Arbovirus Initiative is an integrated strategic plan to tackle emerging and re-emerging arboviruses with epidemic and pandemic potential focusing on monitoring risk, pandemic prevention, preparedness, detection and response, and building a coalition of partners (WHO, 2022b).

Risk Management: During outbreaks, insecticides may be sprayed to kill flying mosquitoes, applied to surfaces in and around containers where the mosquitoes land, and used to treat water in containers to kill the immature larvae. This may also be performed by health authorities as an emergency measure to control the mosquito population (WHO, 2025).

For protection during outbreaks of chikungunya, clothing which minimises skin exposure to the day-biting vectors is advised. Repellents can be applied to exposed skin or to clothing in strict accordance with product label instructions. Repellents should contain DEET, IR3535 or icaridin. For those who sleep during the daytime, particularly young children, or sick or older people, insecticide-treated mosquito nets afford good protection, because the mosquitoes that transmit chikungunya feed primarily during the day. Basic precautions should be taken by people travelling to risk areas and these include the use of repellents, wearing long sleeves and pants and ensuring rooms are fitted with screens to prevent mosquitoes from entering (WHO, 2025).

There is no specific antiviral drug treatment for chikungunya. Clinical management targets are primarily for relieving the symptoms. There is no commercial vaccine available to protect against chikungunya virus infection. While there are several vaccine strategies being pursued (as of mid-2020), of which some are in various stages of clinical trials, they are still several years away from being licensed and available to the public. Prevention of infection by avoiding mosquito bites is the best protection (WHO, 2025).

Preliminary – Corrections Pending

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https://www.who.int/emergencies/surveillance/early-warning-alert-and-response-system-ewars Accessed 1 November 2024.

Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0204 / BIOLOGICAL / Infectious Diseases (Human and Animal

Cholera (Human)

Definition

Cholera is an acute diarrhoeal infection caused by ingestion of food or water contaminated with the bacterium *Vibrio cholerae*. Cholera is a global threat to public health (WHO, 2024a).

Reference

WHO, 2024a. Cholera. World Health Organization (WHO). https://www.who.int/news-room/fact-sheets/detail/cholera . Accessed 24 May 2025.

Annotations

Synonyms

Dysentery, Asiatic cholera, Epidemic cholera.

Additional scientific description

During the 19th century, cholera spread across the world from its original reservoir in the Ganges delta in India. Six subsequent pandemics killed millions of people across all continents. The current (seventh) pandemic started in South Asia in 1961 and reached Africa in 1971 and the Americas in 1991. Cholera is now endemic in many countries (WHO, 2024a).

There are many serogroups of V. cholerae, but only two – O1 and O139 – cause outbreaks. V. cholerae O1 has caused all recent outbreaks. *V. cholerae* O139 – first identified in Bangladesh in 1992 – has caused outbreaks in the past but recently has only been identified in sporadic cases. It has never been identified outside Asia. There is no difference in the illness caused by the two serogroups. These are extremely virulent, and it usually takes between twelve hours and five days for symptoms to develop following infection (WHO, 2024a).

The disease can affect both adults and children. Most of those infected with Vibrio cholerae do not develop any symptoms, although the bacteria are present in their faeces for one to ten days after infection, and are shed back into the environment, potentially affecting other people. Among people who develop symptoms, the majority have mild or moderate symptoms, while a minority develop acute watery diarrhoea which can lead to death if untreated. Treatment should be rapid, with intravenous fluids and antibiotics (WHO, 2024a).

Cholera diagnosis is confirmed by identifying Vibrio cholerae in the stools of affected individuals. Detection can be facilitated by the use of rapid diagnostic tests (RDTs) where one, or more, positive sample(s) triggers a cholera alert, but confirmation requires laboratory testing by culture, seroagglutination or polymerase chain reaction (PCR) (WHO, 2024a).

Cholera can be endemic or epidemic. A cholera-endemic area is an area where confirmed cholera cases were detected during the last three years with evidence of local transmission (meaning the cases are not imported from elsewhere). (WHO, 2024a). A cholera outbreak/epidemic can occur in both endemic countries and in countries where cholera does not regularly occur.

In cholera endemic countries an outbreak can be seasonal or sporadic and represents a greater than expected number of cases. In a country where cholera does not regularly occur, an outbreak is defined by the occurrence of at least one confirmed case of cholera with evidence of local transmission in an area where there is not usually cholera (WHO, 2024a).

The number of cholera cases reported to the World Health Organization (WHO) has continued to be high over the last few years. During 2023, 535 321 cases and 4007 deaths were reported to WHO from 45 countries, territories and areas, an increase from 44 in 2022 and 35 in 2021(WHO, 2024b). The discrepancy between these figures and the estimated burden of the disease is because many cases are not recorded due to limitations in surveillance systems and fear of impact on trade and tourism (WHO, 2024b).

Metrics and numeric limits

Researchers have estimated that every year, there are roughly 1.2 to 4.0 million cases, and 21,000 to 143,000 deaths worldwide due to cholera (WHO, 2019). Cholera can be endemic or epidemic. A cholera-endemic area is an area where confirmed cholera cases were detected during the last three years, with evidence of local transmission (WHO, 2024a).

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The WHO has published guidance for Controlled Temperature Chain (CTC), case definitions and surveillance (GTFCC, 2024; WHO, 2024c; no date a).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Cholera remains a global threat to public health and an indicator of inequity and lack of social development. The provision of safe water and sanitation is critical for the prevention and control of cholera (WHO, 2019).

Cholera transmission is closely linked to inadequate access to clean water and sanitation facilities. Typical at-risk areas include peri-urban slums, as well as camps for internally displaced persons or refugees. The consequences of a humanitarian crisis – such as disruption of water and sanitation systems, or the displacement of populations to inadequate and overcrowded camps – can increase the risk of cholera transmission, should the bacteria be present or introduced. Uninfected dead bodies have never been reported as the source of the epidemic (WHO, 2024a).

Cholera outbreaks occur regularly in some countries. In others, they are less frequent, and it may be years between outbreaks. Cholera is linked to limited access to safe water, basic sanitation facilities and poor hygiene practices. This may be due to conflict, population displacement, climate events like cyclones, floods, earthquakes or drought, and lack of investment in maintaining and improving WASH services and infrastructure (WHO, 2024a). These factors exacerbate the spread of cholera and make it harder to control. Disease surveillance and early warning systems, coupled with effective prevention and response capabilities, can reduce current and future vulnerability to infectious diseases following flooding (Brown and Murray, 2013)

Impacts: Cholera is a severe diarrheal disease that can be fatal within hours if not treated. Quick access to treatment is crucial. Researchers estimate that there are 1.3 to 4.0 million cases and 21 000 to 143 000 deaths from cholera worldwide each year (WHO, 2024a).

Multi-hazard Context: Disaster-affected people eating food from centralized kitchens that are not properly equipped, or run are extremely vulnerable to outbreaks of foodborne disease. The combination of environmental contamination and improper handling of food increases the risk of epidemics of diseases such as cholera. Cholera can spread very quickly in overcrowded living areas such as refugee camps (WHO, 2002).

Monitoring: Cholera surveillance should be part of an integrated disease surveillance system that includes feedback at the local level and information-sharing at the global level. Cholera cases are detected based on clinical suspicion in patients who present with severe acute watery diarrhoea. The suspicion is then confirmed by identifying V. cholerae in stool samples from affected patients. Detection can be facilitated using rapid diagnostic tests where one, or more, positive sample(s) triggers a cholera alert. The samples are sent to a laboratory for confirmation by culture or PCR. Local capacity to detect (diagnose) and monitor (collect, compile, and analyse data) cholera occurrence, is central to an effective surveillance system and to planning control measures. Countries affected by cholera are encouraged to strengthen disease surveillance and national preparedness to rapidly detect and respond to outbreaks. Under the International Health Regulations, notification of all cases of cholera is no longer mandatory (WHO, 2024). However, public health events involving cholera must always be assessed against the criteria provided in the regulations to determine whether there is a need for official notification (WHO, 2014; 2024a).

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country's risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date b).

Risk Management: A multifaceted approach is key to control cholera, and to reduce deaths (WHO, 2024a). A combination of surveillance, water, sanitation and hygiene, social mobilisation, treatment, and oral cholera vaccines are used.

Water and sanitation interventions. The long-term solution for cholera control lies in economic development and universal access to safe drinking water and adequate sanitation. Actions targeting environmental conditions include the implementation of adapted long-term sustainable WASH solutions to ensure the use of safe water, basic sanitation and good hygiene practices in cholera hotspots (WHO, 2024a). In addition to cholera, such interventions prevent a wide range of other water-borne illnesses, as well as contribute to achieving Sustainable Development Goals related to poverty, malnutrition, and education. The WASH solutions for cholera are aligned with those of the Sustainable Development Goals (SDG 6) (WHO, 2024a).

Treatment: Cholera is an easily treatable disease. The majority of people can be treated successfully through prompt

Preliminary – Corrections Pending

administration of oral rehydration solution. Severely, dehydrated patients are at risk of shock and require the rapid administration of intravenous fluids. These patients are also given appropriate antibiotics to diminish the duration of diarrhoea, reduce the volume of rehydration fluids needed, and shorten the amount and duration of V. cholerae excretion in their stool. Rapid access to treatment is essential during a cholera outbreak. Oral rehydration should be available in communities, in addition to larger treatment centres that can provide intravenous fluids and 24-hour care. With early and proper treatment, the case fatality rate should remain below 1% (WHO, 2024a).

Hygiene promotion and social mobilisation. Health education campaigns, adapted to local culture and beliefs, should promote the adoption of appropriate hygiene practices such as handwashing with soap, safe preparation and storage of food and safe disposal of the faeces of children. Funeral practices for individuals who die from cholera must be adapted to prevent infection among attendees. Further, awareness campaigns should be organised during outbreaks, and information should be provided to the community about the potential risks and symptoms of cholera, precautions to take to avoid cholera, when and where to report cases and to seek immediate treatment when symptoms appear. The location of appropriate treatment sites should also be shared. Community engagement is key to long-term changes in behaviour and to the control of cholera (WHO, 2024a).

Oral cholera vaccines. Currently, there are three WHO pre-qualified oral cholera vaccines: Dukoral®, Shanchol™, and Euvichol-Plus®. All three vaccines require two doses for full protection. More than 30 million doses of oral cholera vaccines have been used in mass vaccination campaigns. The campaigns have been implemented in areas experiencing an outbreak, in areas at heightened vulnerability during humanitarian crises, and among populations living in highly endemic areas, known as 'hotspots' always in conjunction with other cholera prevention and control strategies; vaccination should not disrupt the provision of other high priority health interventions to control or prevent cholera outbreaks; (WHO, 2014a; no date c).

The Global Task Force on Cholera Control (GTFCC), with its Secretariat based at WHO, was revitalized in 2014. The GTFCC is a network of more than 50 partners active in cholera control globally, including academic institutions, non-governmental organizations and United Nations agencies. To strengthen GTFCC support to countries, in 2020 a Country Support Platform (CSP) was established. The CSP, hosted by the International Federation of Red Cross and Red Crescent Societies (IFRC) provides multisectoral operational support as well as advocacy, coordination and policy guidance necessary for countries to develop, fund, implement and monitor their National Cholera Plans (NCPs) effectively in alignment with the Global Roadmap. In October 2017, GTFCC partners launched a strategy for cholera control Ending cholera: a global roadmap to 2030. The country-led strategy aims to reduce cholera deaths by 90% and to eliminate cholera in as many as 20 countries by 2030 (WHO, 2024a).

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0205 / BIOLOGICAL / Infectious Diseases (Human and Animal)

zoonosis

COVID-19 (SARS-CoV-2) (Human and Animal)

Definition

COVID-19 is an infectious disease caused by the SARS Coronavirus 2 (SARS-CoV-2), a virus first identified in human populations in late 2019 which caused a global outbreak of coronavirus – an infectious disease caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (adapted from WHO, 2023 and WHO Euro, no date).

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Annotations

Synonyms

Severe Acute Respiratory Syndrome Coronavirus 2. SARS-CoV-2. Coronavirus, COVID-19.

Additional scientific description

COVID-19 is the disease caused by the SARS-CoV-2 coronavirus. It usually spreads between people in close contact (WHO, 2023a)

Cases of novel coronavirus (nCoV) were first detected in China in December 2019, with the virus spreading rapidly to other countries across the world. This led WHO to declare a Public Health Emergency of International Concern (PHEIC) on 30 January 2020 and to characterize the outbreak as a pandemic on 11 March 2020 (WHO Euro, 2025).

On 5 May 2023, more than three years into the pandemic, the WHO Emergency Committee on COVID-19 recommended to the Director-General, who accepted the recommendation, that given the disease was by now well established and ongoing, it no longer fit the definition of a PHEIC. This does not mean the pandemic itself is over, but the global emergency it caused is for now. A review committee will be established to develop long-term, standing recommendations for countries on how to manage COVID-19 on an ongoing basis (WHO Euro, 2025).

COVID-19 vaccines provide strong protection against severe illness and death. Although a person can still get COVID-19 after vaccination, they are more likely to have mild or no symptoms. Anyone can get sick with COVID-19 and become seriously ill or die, but most people will recover without treatment (WHO, 2023a).

People may experience different symptoms of COVID-19. Symptoms usually begin 5-6 days after exposure and last 1-14 days. The most common symptoms are fever, chills and sore throat. The less common symptoms include muscle aches and heavy arms or legs, severe fatigue or tiredness, runny or blocked nose, or sneezing, headache, sore eyes, dizziness, new and persistent cough, tight chest or chest pain, shortness of breath, hoarse voice, numbness or tingling, appetite loss, nausea, vomiting, abdominal pain or diarrhoea, loss or change of sense of taste or smell and difficulty sleeping (WHO, 2023a).

Preliminary – Corrections Pending

Two main types of tests can confirm whether you are infected with SARS-CoV-2, the virus that causes COVID-19. Molecular tests, such as polymerase chain reaction (PCR), are the most accurate tests for diagnosing SARS-CoV-2 infection. Molecular tests detect viruses in the sample by amplifying viral genetic material to detectable levels. Rapid antigen tests (sometimes known as rapid diagnostic tests or RDTs) detect viral proteins (known as antigens). RDTs are a simpler and faster option than molecular tests and are available for testing by trained operators or by the individual themselves (sometimes called self-tests). They perform best when there is more virus circulating in the community and when sampled from an individual during the time they are most infectious, generally within the first 5-7 days following symptom onset. Samples for both types of tests are collected from the nose and/or throat with a swab (WHO, 2023b).

Between 2020 and 2024, SARS-CoV-2 infections were also reported in several animal species in 34 countries including Anteater, armadillo, gorilla, mandrill, and other monkey species, various cat species including lynx, lion, tiger, leopard, dog fox, and hyena, horse, cattle, deer, pig, mink, ferret and otter, rabbit and rodent, and even in a captive manatee, according to WOAH World Animal Health Information System (WOAH, no date).

The World Health Organization (WHO) has published many advice documents, technical documents, situation reports, response updates and research documents for COVID-19. These include travel advice, surveillance, diagnosis, treatment and vaccination guidelines and frameworks (WHO, 2025b).

Metrics and numeric limits

The global statistical information is summarized on the WHO COVID-19 Dashboard (WHO, 2025b) as follows:

- As of 30 March 2025, 777,691,501 number of COVID-19 cases had been reported to WHO (total cumulative cases)
- As of 20 March 2025, 7,093,267 number of COVID-19 deaths had been reported to WHO (total cumulative COVID-19 deaths)
- As of 31 December 2023, 13.64bn vaccine doses have been administered globally
- As of 31 December 2023, 67% of the total global population had been vaccinated with a complete primary series of a COVID-19 vaccine
- As of 31 December 2023, 32% of the total global population had been vaccinated with at least one booster dose of a COVID-19 vaccine

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of drivers, impacts, and risk management

Hazard Drivers: COVID-19 is the disease caused by the SARS-CoV-2 coronavirus. It usually spreads between people in close contact (WHO, 2023a). Cases of novel coronavirus (nCoV) were first detected in China in December 2019, with the virus spreading rapidly to other countries across the world (WHO Euro, 2025).

WHO reports that the virus spreads mainly between people who are in close contact with each other, for example at a conversational distance when they cough, sneeze, speak, sing or breathe (short-range airborne transmission) or droplet transmission. The virus can also spread in poorly ventilated and/or crowded indoor settings, where people tend to spend longer periods of time with the virus suspended in the air or travel farther than conversational distance (long-range airborne transmission). Infection can also spread through touching the eyes, nose or mouth after touching surfaces or objects that have been contaminated by the virus (WHO, 2021a).

Impact: Cases of novel coronavirus (nCoV) were first detected in China in December 2019, with the virus spreading rapidly to other countries across the world which led WHO to declare a Public Health Emergency of International Concern (PHEIC) on 30 January 2020 (WHO Euro, 2025).

People with the following symptoms were requested to seek immediate medical attention: difficulty breathing, especially at rest, or unable to speak in sentences, confusion, drowsiness or loss of consciousness, persistent pain or pressure in the chest, skin being cold or clammy, or turning pale or a bluish colour and loss of speech or movement (WHO, 2023a).

People who have pre-existing health problems are at higher risk when they have COVID-19; these include people taking immunosuppressive medication; those with chronic heart, lung, liver or rheumatological problems; those with HIV, diabetes, cancer, obesity or dementia. People with severe disease and those needing hospital treatment should receive treatment as soon as possible. The consequences of severe COVID-19 include death, respiratory failure, sepsis, thromboembolism (blood clots), and multiorgan failure, including injury of the heart, liver or kidneys (WHO, 2023a). In rare situations, children can develop severe inflammatory syndrome a few weeks after infection (WHO, 2023a).

Preliminary – Corrections Pending

Some people who have had COVID-19, whether they have needed hospitalization or not, continue to experience symptoms. These long-term effects are called long COVID (or post-COVID-19 condition). The most common symptoms associated with long COVID include fatigue, breathlessness and cognitive dysfunction (for example, confusion, forgetfulness, or a lack of mental focus or clarity). Long COVID can affect a person's ability to perform daily activities such as work or household chores (WHO, 2023a).

As of 30 March 2025, 777,691,501 COVID-19 cases had been reported to WHO with 7,093,267 COVID-19 deaths (WHO, 2025a).

Nearly five years since the first SARS-CoV-2 infections were reported, the global COVID-19 situation has changed substantially. With widespread immunity from both vaccination and prior infection, currently circulating variants are now associated with lower severe disease rates and fewer hospitalizations. As a result, most countries have lifted public health and social measures and have moved to end their national COVID-19 emergencies (WHO, 2023b).

COVID-19 continues to circulate widely, however, presenting significant challenges to health systems worldwide. Tens of thousands of people are infected or re-infected with SARS-CoV-2 each week. It is vital that countries sustain the public health response to COVID-19 amid ongoing illness and death and the emergence of SARS-CoV-2 variants, adapting it to the requirements based on the current COVID-19 situation and risk (WHO, 2023b).

In 2022 and 2023, WHO released a package of policy briefs designed to help countries formulate policies to manage SARS-CoV-2 transmission, particularly in high-risk and vulnerable populations, and to reduce morbidity, mortality and long-term sequelae from COVID-19. The policy briefs have been updated to reflect the current COVID-19 situation and risk and the approaches outlined in the September 2023 WHO document Ending the COVID-19 emergency and transitioning from emergency phase to longer-term disease management: Guidance on calibrating the response and the Director-General's standing recommendations for COVID-19 (WHO, 2023b).

Multi-hazard Context: From one of the many reports on the impact of COVID-10, the Independent Panel for Pandemic Preparedness & Response COVID-19: Make it the Last Pandemic. was published in 2021 and presented at the UN General Assembly in a special session. As of April 2021, they reported that COVID-19 has shown how an infectious disease can sweep the globe in weeks and, in the space of a few months, set back sustainable development by years (Independent Panel, 2021). By all measures, the impact of the pandemic is massive as of 28 April 2021. They summarised the data as the numbers who were infected by the virus and the deaths reported in 223 countries, territories and areas, with the impact on health workers mortality and the economic impacts. They also reported that at its highest point in 2020, 90% of schoolchildren were unable to attend school with 10 million more girls at risk of early marriage because of the pandemic (Independent Panel, 2021). They noted that gender-based violence support services have seen fivefold increases in demand. The authors were concerned it was probable that 115-125 million people have been pushed into extreme poverty (Independent Panel, 2021).

Monitoring: The section and the table below offer an overview of monitoring for COVID-19. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

1. Which institution(s) produce(s) Disaster Risk Data/Information?	Ministry of Health and the IHR National Focal Point, WHO, FAO Reference Centres, WOAH Reference Centres
2.a. How is the Hazard Monitored / Observed / Forecast?	FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

Under the implementation of the International Health Regulations (IHR), countries were advised to sustain collaborative surveillance for COVID-19, in order to provide a basis for situational awareness and risk assessment and the detection of significant changes in virus characteristics, virus spread, disease severity and population immunity, as per the standing recommendations for COVID-19 issued by the WHO Director-General (WHO, 2024).

Core surveillance activities for SARS-CoV-2 provide early warnings of changes in epidemiological patterns, monitor circulation and the emergence of new SARS-CoV-2 variants and enable monitoring of both morbidity and mortality trends and disease burden on health care capacities (health and care workers, hospitalizations and intensive care unit admissions) (WHO, 2024).

These activities also measure the longer-term impacts of Post-COVID conditions (also known as Long COVID). Incorporating strategic and geographically representative genomic surveillance enables the monitoring of the circulation of SARS-CoV-2 variants of concern (VOCs), early detection of new variants of interest (VOIs) and tracking of SARS-CoV-2 in potential animal reservoirs, along with other changes in virological patterns (WHO, 2024).

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country's risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar,

Preliminary – Corrections Pending

countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021b).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a disaster from natural hazards. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023c).

Risk Management: To prevent the spread of COVID-19 (WHO, 2023a):

- avoid crowds and keep a safe distance from others, even if they don't appear to be sick;
- wear a properly fitted mask if you feel sick, have been close to people who are sick, if you are at high risk, or in crowded or poorly ventilated areas;
- clean your hands frequently with alcohol-based hand rub or soap and water;
- cover your mouth and nose with a bent elbow or tissue when you cough or sneeze;
- dispose of used tissues right away and clean your hands; and
- if you develop symptoms or test positive for COVID-19, self-isolate until you recover.

COVID-19 vaccines provide strong protection against serious illness, hospitalization and death. Vaccination against COVID-19 is based on priority groups such as people aged 60 years and over, and those with underlying medical problems such as high blood pressure, diabetes, chronic health problems, immunosuppression (including HIV), obesity, cancer, pregnant persons, and unvaccinated people. In March 2023, WHO updated its recommendations on primary series vaccination (two doses of any vaccine) as well as the need for booster doses. These recommendations are time-limited and can change at any time depending on how the SARS-CoV-2 virus is circulating in your area or country. It is important to stay up to date with local guidelines and recommendations provided by your local health authority (WHO, 2023a).

Since its introduction, COVID-19 vaccines have saved millions of lives across the world by providing protection against severe disease, hospitalization, and death. Even though vaccines protect against severe disease and death, it is still possible to spread SARS-CoV-2 to others after being vaccinated (WHO, 2023a).

WHO is the global coordinating agency for the response to the COVID-19 pandemic. The Organization works with Member States and partners on all aspects of the pandemic response, including facilitating research, developing guidance, coordinating vaccine development and distribution, and monitoring daily case numbers and trends around the world. Since April 2020, the Access to COVID-19 Tools (ACT) Accelerator, launched by WHO and its partners, has supported the fastest, most coordinated, and most successful global effort in history to develop tools to fight a disease. COVAX, the vaccines pillar of the ACT-Accelerator is a ground-breaking global collaboration to accelerate the development, production, and equitable access to COVID-19 tests, treatments, and vaccines. WHO provides global coordination and Member-state support on vaccine safety monitoring. It developed the target product profiles for COVID-19 vaccines and provides R&D technical coordination. WHO also leads work to improve global capacity and access to oxygen production, distribution and supply to patients (WHO, 2023a).

As many countries discontinue COVID-19-specific reporting and integrate it into respiratory disease surveillance, WHO will use all available sources to continue monitoring the COVID-19 epidemiological situation, especially data on illness and impact on health systems. COVID-19 remains a major threat, and WHO urges Member States to maintain, not dismantle, their established COVID-19 infrastructure. It is crucial to sustain early warning, surveillance and reporting, variant tracking, early clinical care provision, administration of vaccine to high-risk groups, improvements in ventilation, and regular communication. As of February 2025, WHO continued to monitor several SARS-CoV-2 variants, including one variant of interest (VOI) JN.1, and seven variants under monitoring (VUMs). JN.1, the VOI, accounted for 15.0% of sequences in week 1 of 2025. The VUM, XEC and LP.8.1 continue to increase in prevalence, accounting for 44.8% and 4.7%, respectively, of sequences in week 1 of 2025, and are the only tracked variants currently growing in prevalence. All the remaining VUMs are declining in prevalence (WHO, 2025c).

Preliminary – Corrections Pending

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Coordinating agency or organisation

World Health Organization, Food and Agriculture Organization of the United Nations (FAO) and World Organisation for Animal Health (WOAH).

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BI0206 / BIOLOGICAL / Infectious Diseases (Human and Animal)

zoonosis

Crimean-Congo Haemorrhagic Fever (Human and Animal)

Definition

Crimean-Congo haemorrhagic fever (CCHF) is a tick-borne viral infection caused by the CCHF virus. It causes severe viral haemorrhagic fever outbreaks and epidemics. CCHF outbreaks have a case fatality rate of 10-40% (WHO, 2025).

Reference

WHO, 2025. Crimean-Congo haemorrhagic fever. World Health Organization (WHO). https://www.who.int/news-room/fact-sheets/detail/crimean-congo-haemorrhagic-fever Accessed 26 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Not identified.

Additional scientific description

The Crimean-Congo haemorrhagic fever (CCHF) virus is a tick-borne virus (Nairovirus) of the Bunyaviridae family. The virus is primarily transmitted to people from ticks and livestock animals. Human-to-human transmission can occur resulting from close contact with the blood, secretions, organs or other bodily fluids of infected persons. CCHF is endemic in Africa, the Balkans, the Middle East and Asia, in countries south of the 50th parallel north. (WHO, 2025)

The hosts of the CCHF virus include a wide range of wild and domestic animals such as cattle, sheep and goats. Many birds are resistant to infection, but ostriches are susceptible and may show a high prevalence of infection in endemic areas, where they have been at the origin of human cases. There is no apparent disease in these animals (WHO, 2025).

There is no vaccine available for either people or animals (WHO, 2025).

Human
The CCHF virus is transmitted to humans either by tick bites (principally ticks of the genus Hyalomma) or through contact with infected animal blood or tissues during and immediately after slaughter. Human-to-human transmission can occur from close contact with the blood, secretions, organs or other bodily fluids of infected persons. Hospital-acquired infections can also occur due to improper sterilisation of medical equipment and reuse of non-sterile needles (WHO, 2025). The length of the incubation period depends on the mode of acquisition of the virus. Following infection by a tick bite, the incubation period is usually one to three days, with a maximum of nine days. The incubation period following contact with infected blood or tissues is usually five to six days, with a documented maximum of thirteen days (WHO, 2025). The disease was first described in Crimea in 1944 and given the name Crimean haemorrhagic fever. In 1969 it was recognised that the pathogen causing Crimean haemorrhagic fever was the same as that responsible for an illness identified in 1956 in Congo. The linkage of the two place names resulted in the current name for the disease and the virus (WHO, 2024a).
Animal
Crimean–Congo haemorrhagic fever (CCHF) is a zoonotic disease in many countries of Asia, Africa, the Middle East and southeastern Europe. The virus circulates in a tick–vertebrate–tick cycle but can also be transmitted horizontally and vertically within the tick population. Hyalomma ticks infest a wide spectrum of different wildlife species, e.g. deer and hares, and free-ranging livestock animals, e.g. goat, cattle, and sheep. These animals play a crucial role in the life cycle of ticks, and in the transmission and amplification of the virus. As animals do not develop clinical signs, CCHFV infections have no economic impact on livestock animal production (WOAH, 2024). Any CCHF-related specimens from suspected or confirmed human or animal cases must be transported as UN2814 using P620 packaging on any mode

of transport (United Nations, 2023).

Metrics and numeric limits

The European Centre for Disease Prevention and Control (ECDC) has published case definitions on Crimean-Congo haemorrhagic fever prevention and control (ECDC, 2008). WHO also provides documentation to help disease investigation and control and has created an aide-memoire on standard precautions in health care, which is intended to reduce the risk of transmission of bloodborne and other pathogens (WHO, 2024b).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

United Nations. 2023. UN Recommendations on the Transport of Dangerous Goods - UN Model Regulations. https://unece.org/transport/dangerous-goods/un-model-regulations-rev-23

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: The CCHF virus is transmitted to people either by tick bites or through contact with infected animal blood or tissues during and immediately after slaughter. The majority of cases have occurred in people involved in the livestock industry, such as agricultural workers, slaughterhouse workers and veterinarians (Ergönül, 2006).

Human-to-human transmission can occur resulting from close contact with the blood, secretions, organs or other bodily fluids of infected persons. Hospital-acquired infections can also occur due to improper sterilization of medical equipment, reuse of needles and contamination of medical supplies. In the absence of a vaccine, the only way to reduce Crimean-Congo haemorrhagic fever infection in people is by raising awareness of the risk factors and educating people about the measures for reducing exposure (WHO, 2025).

Impacts: Onset of symptoms is sudden and can include fever, muscle ache, dizziness, neck pain, backache, headache, sore eyes and photophobia (sensitivity to light). There may be nausea, vomiting, diarrhoea, abdominal pain and sore throat early on, followed by sharp mood swings and confusion. After 2-4 days the agitation may be replaced by sleepiness, depression and lassitude, and the abdominal pain may localize to the upper right quadrant, with detectable hepatomegaly (liver enlargement) (WHO, 2024a).

Other clinical signs include tachycardia (fast heart rate), lymphadenopathy (enlarged lymph nodes), and a petechial rash (a rash caused by bleeding into the skin) on internal mucosal surfaces, such as in the mouth and throat, and on the skin. The petechiae may give way to larger rashes called ecchymoses, and other haemorrhagic phenomena. There is usually evidence of hepatitis, and severely ill patients may experience rapid kidney deterioration, sudden liver failure or pulmonary failure after the fifth day of illness (WHO, 2024a).

Multi-hazard Context: CCHF has been observed where conflicts are on-going and in areas where humans are in close contact with wild animals carrying the virus (Ergönül, 2006). Changes in climatic conditions have been suggested to be one of the factors that has facilitated reproduction of the tick population, and consequently the increased incidence of tick-borne infectious diseases (Ergönül, 2006).

Monitoring: WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a disaster from natural hazards. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023).

The section and the table below offer an overview of monitoring for Crimean-Congo haemorrhagic fever. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	WHO
How is the Hazard Observed/Monitored/Forecast?	FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

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Risk Management: It is difficult to prevent or control CCHF infection in animals and ticks as the tick-animal-tick cycle usually goes unnoticed and the infection in domestic animals is usually not apparent. Furthermore, the tick vectors are numerous and widespread, so tick control with acaricides (chemicals intended to kill ticks) is only a realistic option for well-managed livestock production facilities. There are no vaccines available for use in animals (WHO, 2024a).

Although an inactivated, mouse brain-derived vaccine against CCHF has been developed and used on a small scale in eastern Europe, there is currently no safe and effective vaccine widely available for human use.

In the absence of a vaccine, the only way to reduce infection in people is by raising awareness of the risk factors and educating people about the measures they can take to reduce exposure to the virus (WHO, 2025). Public health advice should focus on several aspects such as reducing the risk of tick-to-human transmission: wearing protective clothing (long sleeves, long trousers); wearing light coloured clothing to allow easy detection of ticks on the clothes; using approved acaricides (chemicals intended to kill ticks) on clothing; using approved repellent on the skin and clothing; regularly examining clothing and skin for ticks; if found, remove them safely; seeking to eliminate or control tick infestations on animals or in stables and barns; and avoiding areas where ticks are abundant and seasons when they are most active (WHO, 2025).

Health-care workers caring for patients with suspected or confirmed CCHF, or handling specimens from them, should implement standard infection control precautions. These include basic hand hygiene, use of personal protective equipment, safe injection practices and safe burial practices (WHO, 2025).

WHO is working with partners to support CCHF surveillance, diagnostic capacity and outbreak response activities in Europe, the Middle East, Asia and Africa (WHO, 2023).

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0207 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Dengue (Human)

Definition

Dengue is a mosquito-borne disease that is caused by a virus of the Flaviviridae family and transmitted by female mosquitoes mainly of the species *Aedes aegypti* and, to a lesser extent, *A. albopictus*. The incidence of dengue has grown dramatically around the world in recent decades, with cases reported to WHO increasing from 505 430 cases in 2000 to 5.2 million in 2019 (adapted from WHO, 2024).

Reference

WHO, 2024. Dengue and severe dengue. World Health Organization (WHO). https://www.who.int/news-room/fact-sheets/detail/dengue-and-severe-dengue Accessed 29 May 2025

Preliminary – Corrections Pending

Annotations

Synonyms

Break Bone Fever.

Additional scientific description

Dengue is a mosquito-borne viral disease that is transmitted by female mosquitoes mainly of the species *Aedes aegypti*. Other species within the *Aedes* genus can also act as vectors, but their contribution is normally secondary to *Aedes aegypti*. However, in 2023, a surge in local transmission of dengue by *Aedes albopictus* (tiger mosquito) has been seen in Europe (WHO, 2024a).

These mosquitoes are also vectors of chikungunya, yellow fever and Zika viruses. Dengue is widespread throughout the tropics, with local variations in risk influenced by rainfall, temperature, relative humidity and unplanned rapid urbanisation (WHO, 2024a).

Dengue poses an increasingly large public health threat, with an estimated 3.8 billion people (95% confidence interval [CI]: 3.5 billion–4.1 billion) living in areas at risk of the disease, most of which are in Asia, Africa, and the Americas in 2015. Urbanization with increasing population densities, population movement, and climate change have led to the geographical expansion of the Aedes vector species and thus contributed to the increase in dengue incidence. There are an estimated 100–400 million infections each year (WHO, 2024b).

The disease is now endemic in more than 100 countries in the WHO Regions of Africa, the Americas, the Eastern Mediterranean, South-East Asia and the Western Pacific. The Americas, South-East Asia and Western Pacific regions are the most seriously affected, with Asia representing around 70% of the global disease burden. Dengue is spreading to new areas in Europe, the Eastern Mediterranean and South America (WHO, 2024a).

Dengue is a severe, flu-like illness that affects infants, young children and adults, but seldom causes death. Symptoms usually last for 2–7 days, after an incubation period of 4–10 days after the bite from an infected mosquito (WHO, 2024a).

Dengue causes a wide spectrum of diseases, ranging from subclinical disease (people may not know they are even infected) to severe flu-like symptoms in those infected. Although less common, some people develop severe dengue, which can be any number of complications associated with severe bleeding, organ impairment and/or plasma leakage. Severe dengue has a higher risk of death when not managed appropriately. (WHO, 2024a).

Mosquitoes can become infected by people who are viremic with the dengue virus. This can be someone who has a symptomatic dengue infection, someone who is yet to have a symptomatic infection (they are pre-symptomatic), and also someone who shows no signs of illness (they are asymptomatic). Human-to-mosquito transmission can occur up to 2 days before someone shows

symptoms of the illness, and up to 2 days after the fever has resolved.

The risk of mosquito infection is positively associated with high viremia and high fever in the patient; conversely, high levels of DENV-specific antibodies are associated with a decreased risk of mosquito infection. Most people are viremic for about 4-5 days, but viremia can last as long as 12 days. Following infection with one DENV serotype, antibodies that are serotype-specific (homotypic) and cross-reactive with other serotypes (heterotypic) are induced. Following a primary infection with one DENV serotype, long-lasting homotypic protection is elicited. Cross-reactive heterotypic protection, however, is short-term and declines rapidly within a matter of 2 years. As heterotypic protection wanes, there is a risk of severe dengue following a second infection with another serotype.

There is no specific antiviral treatment for dengue, so measures to prevent severe disease and death rely primarily on supportive management with volume replacement. Patients with severe dengue often require in-hospital management in intensive care settings to mitigate poor clinical outcomes that may be caused by vascular leakage or severe bleeding.

The WHO recommends three methods of dengue surveillance: epidemiological surveillance, vector surveillance and monitoring behavioural impact (WHO, no date).

Metrics and numeric limits

Since the beginning of 2023 ongoing transmission, combined with an unexpected spike in dengue cases, resulted in a historic high of over 6.5 million cases and more than 7300 dengue-related deaths reported. The WHO Region of the Americas reported 4.5 million cases, with 2300 deaths. A high number of cases were reported in Asia: Bangladesh (321 000), Malaysia (111 400), Thailand (150 000), and Vietnam (369 000) (WHO, 2024a).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: The primary mode of transmission of the dengue virus between humans involves mosquito vectors. There is evidence, however, of the possibility of maternal transmission (from a pregnant mother to her baby). At the same time, vertical transmission rates appear low, with the risk of vertical transmission seemingly linked to the timing of the dengue infection during the pregnancy. When a mother does have a dengue infection when she is pregnant, babies may suffer from pre-term birth, low birthweight, and foetal distress (WHO, 2024a).

Rare cases of transmission via blood products, organ donation and transfusions have been recorded. Similarly, transovarial transmission of the virus within mosquitoes has also been recorded. Previous infection with DENV increases the risk of the individual developing severe dengue (WHO, 2024a).

Impacts: The highest number of dengue cases was recorded in 2023, affecting over 80 countries in all regions of WHO. Since the beginning of 2023, ongoing transmission, combined with an unexpected spike in dengue cases. Several factors are associated with the increasing risk of spread of the dengue epidemic: the changing distribution of the vectors (chiefly *Aedes aegypti* and *Aedes albopictus* mosquitoes), especially in previously dengue naïve countries; the consequences of El Niño phenomena in 2023 and climate change leading to increasing temperatures and high rainfall and humidity; fragile health systems in the midst of the COVID-19 pandemic; and political and financial instabilities in countries facing complex humanitarian crises and high population movements (WHO, 2024a).

Community risks to dengue also depend on a population's knowledge, attitude and practice towards dengue, as the exposure is closely related to behaviours such as water storage, plant keeping, and self-protection against mosquito bites. Routine vector surveillance and control activities engaging communities greatly enhance a community's resilience (WHO, 2024a).

Multi-hazard Context: Urbanization with increasing population densities, population movement, and climate change have led to the geographical expansion of the Aedes vector species and thus contributed to the increase in dengue incidence. Vectors might adapt to new environments and climate. The interaction between the dengue virus, the host and the environment is dynamic. Consequently, disease risks may change and shift with climate change in tropical and subtropical areas, in combination with increased urbanization and movement of populations (WHO, 2024a).

Monitoring: WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country's risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a disaster from natural hazards. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use

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the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023).

Risk Management: The mosquitoes that spread dengue are active during the day. Lower the risk of getting dengue by protecting from mosquito bites by using clothes that cover as much as possible; mosquito nets if sleeping during the day, ideally nets sprayed with insect repellent; window screens; mosquito repellents (containing DEET, Picaridin or IR3535); and coils and vaporizers (WHO, 2024a).

Mosquito breeding can be prevented by preventing mosquitoes from accessing egg-laying habitats through environmental management and modification; disposing of solid waste properly and removing artificial man-made habitats that can hold water; covering, emptying and cleaning domestic water storage containers weekly; and applying appropriate insecticides to outdoor water storage containers (WHO, 2024a).

There are currently 2 licensed dengue vaccines: CYD-TDV (Dengvaxia, Sanofi); and TAK-003 (Qdenga, Takeda). Both are tetravalent live-attenuated vaccines but differ in the extent of chimerization and the genome backbone, as well as in efficacy and safety. Vaccination against dengue should be viewed as part of an integrated strategy to control the disease, including vector control, proper case management, community education, and community engagement. (WHO, 2024b)

Dengue prevention and control depends on effective vector control measures. Sustained community involvement can improve vector control efforts substantially. There is an ongoing need to adhere to other disease preventive measures such as well-executed and sustained vector control using the WHO Integrated Vector Management (IVM) approach, which is a rational decision-making process for the optimal use of resources for vector control (WHO Western Pacific, 2019). Recently some countries have successfully lowered the incidence of arboviral infections such as dengue through vector control with Wolbachia infection of mosquitoes that decreases their ability to transmit arboviruses.

The WHO responds to dengue in the following ways: supports countries in the confirmation of outbreaks through its collaborating network of laboratories; provides technical support and guidance to countries for the effective management of dengue outbreaks; supports countries to improve their reporting systems and capture the true burden of the disease; provides training on clinical management, diagnosis and vector control at the country and regional level with some of its collaborating centres; formulates evidence-based strategies and policies; supports countries in the development of dengue prevention and control strategies and adopting the Global Vector Control Response (2017-2030); reviews the development of new tools, including insecticide products and application technologies; gathers official records of dengue and severe dengue from over 100 Member States; and publishes guidelines and handbooks for surveillance, case management, diagnosis, dengue prevention and control for Member States(WHO, 2024a).

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Coordinating agency or organisation

World Health Organization.

Preliminary - Corrections Pending

BI0208 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Diphtheria (Human)

Definition

Diphtheria is a widespread severe infectious disease caused by the bacterium Corynebacterium diphtheriae and the toxin they produce. It is a potentially life-threatening, vaccine-preventable disease that primarily affects the throat and upper airways and has the potential for epidemics (WHO, 2024a).

Reference

WHO, 2024a. Diphtheria. World Health Organization (WHO). https://www.who.int/news-room/fact-sheets/detail/diphtheria Accessed 16 February 2024.

Preliminary – Corrections Pending

Annotations

Synonyms

Microsporon diphtheriticum, *Bacillus diphtheriae*, and *Mycobacterium diphtheriae*.

Additional scientific description

Diphtheria is a vaccine-preventable disease caused by toxin-producing Corynebacterium species. Diphtheria outbreaks in human populations are primarily caused by *Corynebacterium diphtheriae*, which is spread from person to person, usually through respiratory droplets, secretions or infected skin lesions. Diphtheria may also be caused by *C. ulcerans* or *C. pseudotuberculosis*; however, because these are zoonotic infections, with limited person-to-person transmission, they are rarely associated with large outbreaks (WHO, 2024a; WHO, 2024b).

Typical diphtheria cases present with upper respiratory tract symptoms including pharyngitis, nasopharyngitis, tonsillitis or laryngitis, or any combination of these symptoms. The toxin produced by the bacterium can cause the formation of a pseudo membrane in the upper respiratory tract and may damage other organs. Severe complications include acute respiratory obstruction, acute systemic toxicity, myocarditis, renal failure, neurologic complications and death. Case fatality rates (CFR) above 10% have been reported in diphtheria outbreaks; with higher CFRs appearing in settings where appropriate treatment options, such as diphtheria antitoxin [DAT], is limited (WHO, 2024b).

Following the establishment of the Expanded Programme on Immunization (EPI) in 1974, which included a childhood multivalent vaccine (including diphtheria toxoid), the global incidence of diphtheria decreased dramatically. However, dramatic resurgences of the disease have been seen globally over the past decade, with an average of almost 10,000 cases reported annually – a 50% increase on the decade prior. Although most outbreaks have been small and sporadic, larger outbreaks have occurred in areas of low vaccine coverage or in fragile, conflict-affected settings including Bangladesh, Ethiopia, Haiti, India, Indonesia, Venezuela (Bolivarian Republic of) and Yemen; one of the largest outbreaks of the decade began in 2022 in Nigeria and is still ongoing (WHO, 2024b).

Culture and identification of C. diphtheriae, followed by confirmation of toxin production by Elek testing, remains the gold standard of laboratory confirmation for diphtheria. However, methods including automated identification systems, molecular testing and genotyping can also play a role in informing public health decisions, sometimes more quickly and effectively than standard methods in an outbreak setting. Careful consideration of the benefits and limitations of each method is required to ensure the best use of available resources and alignment with public health goals. (WHO, 2024b).

The World Health Organization has published interim guidance for clinical management and laboratory diagnosis of diphtheria (WHO, 2024a; 2024b).

Metrics and numeric limits

In 2023, there were 24,780 reported cases of diphtheria globally (WHO, 2025).

In 2023, an estimated 84% of children worldwide received the recommended 3 doses of diphtheria-containing vaccine during infancy (WHO, 2024a).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Diphtheria has seen resurgences any time immunization coverage becomes low. Damaged health infrastructure and health services in countries experiencing or recovering from a natural disaster or conflict interrupt routine immunization. Overcrowding in residential camps increases the risk of infection. The COVID-19 pandemic impacted the delivery of routine immunization services and surveillance activities. These setbacks have left many children susceptible to vaccine-preventable diseases such as diphtheria (WHO, 2024a).

Impacts: Diphtheria remains a significant health problem in countries with poor routine vaccination coverage or pockets of unimmunised (WHO, 2017).

The symptoms of diphtheria usually begin 2-5 days after exposure to the bacteria. Typical symptoms of the infection include a sore throat, fever, swollen neck glands and weakness. Within 2-3 days from infection, the dead tissue in the respiratory tract forms a thick, grey coating that can cover tissues in the nose, tonsils and throat, making it hard to breathe and swallow (WHO, 2024a).

Most severe diseases and deaths from diphtheria occur as a result of the diphtheria toxin and its effects. Complications can include inflammation of the heart and nerves (WHO, 2024a).

For unvaccinated individuals without adequate treatment, diphtheria can be fatal in around 30% of cases, with children younger than 5 years of age at greater risk of dying. Any non-immune person (not vaccinated or under-vaccinated) can become infected (WHO, 2024a).

The risk of complications or death decreases considerably if appropriate treatment is provided early in the course of illness. For this reason, if diphtheria is suspected, testing to confirm the disease should be done promptly and treatment should be started as soon as possible. Cases of diphtheria are usually treated with diphtheria antitoxin as well as antibiotics. Diphtheria-specific antitoxin neutralizes circulation toxin in the blood (WHO, 2024a).

Multi-hazard Context: Before the introduction of diphtheria vaccine and widespread vaccination in the 1930s, cases occurred throughout the world (WHO, 2024a).

Recently, as a result of undervaccination, outbreaks have been occurring with increasing frequency despite the availability of a safe and effective vaccine (WHO, 2024a).

Damaged health infrastructure and health services in countries experiencing or recovering from a natural hazard or conflict interrupt routine immunization. Overcrowding in residential camps increases the risk of infection (WHO, 2024a).

Monitoring: WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a disaster from natural hazards. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023).

Risk Management: Diphtheria can be prevented by vaccines that are often given in combination with tetanus and pertussis, and other diseases (WHO, 2024a).

WHO recommends a total of 6 diphtheria-containing vaccine doses be given starting at 6 weeks of age through adolescence to provide long-term protection. Community-wide vaccination with high coverage as a part of routine immunization services embedded in primary health care is the most effective way to prevent diphtheria. All children should be vaccinated against diphtheria with a full primary series and 3 additional booster doses for long-term protection. The vaccine is safe and effective. The diphtheria vaccine is most often combined with vaccines for diseases such as tetanus, pertussis, *Hemophilus influenzae*, hepatitis B and inactivated polio (WHO, 2024a).

The essential programme on immunization began in 1974. Combination diphtheria vaccines were introduced as part of this programme since its inception and have prevented >90% cases of disease between 1980-2000. In recent years, there have been outbreaks of diphtheria due to inadequate vaccine coverage. To control these outbreaks, WHO has worked with member states in outbreak response and in strengthening routine immunization programmes to improve and sustain immunization coverage to prevent diphtheria infections and deaths (WHO, 2024a).

Preliminary – Corrections Pending

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0209 / BIOLOGICAL / Infectious Diseases (Human and Animal)

zoonosis

Ebola (Human and Animal)

Definition

Ebola virus disease (EVD) is a rare but severe zoonotic viral infectious disease caused by the Ebola virus. It can be characterized by haemorrhagic fever and is often fatal in humans. EVD can trigger epidemics with high case-fatality rates (WHO, 2025).

Reference

WHO, 2025. Ebola virus disease. World Health Organization (WHO). https://www.who.int/news-room/fact-sheets/detail/ebola-disease. Accessed 26 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Ebola haemorrhagic fever, Ebola virus disease

Additional scientific description

Human

The Ebola virus causes an acute, serious illness which is often fatal if untreated. Ebola virus disease (EVD) first appeared in 1976 in two simultaneous outbreaks, one in what is now Nzara, South Sudan, and the other in Yambuku, Democratic Republic of Congo. The latter occurred in a village near the Ebola River, from which the disease takes its name (WHO, 2025).

The 2014–2016 outbreak in West Africa was the largest Ebola outbreak since the virus was first discovered in 1976. The outbreak started in Guinea and then moved across land borders to Sierra Leone and Liberia (WHO, no date a). The world's second-largest Ebola outbreak that occurred in North Kivu/Ituri, Democratic Republic of the Congo, August 2018 - June 2020 record was declared over on 25 June 2020. The nearly two yearlong outbreak was particularly challenging because it took place in active conflict zones (WHO, no date b).

Ebola disease is caused by viruses that belong to the *Orthoebolavirus* genus of the Filoviridae family (2). Six species of *Orthoebolaviruses* have been identified to date, The incubation period is from 2 to 21 days (WHO, 2925). A person infected with Ebola virus cannot spread the disease until they develop symptoms. The symptoms of Ebola disease can be sudden and include fever, fatigue, malaise, muscle pain, headache and sore throat. These are followed by vomiting, diarrhoea, abdominal pain, rash, and symptoms of impaired kidney and liver functions. It is important for health and care workers to be on the lookout for these symptoms (WHO, 2025).

It can be difficult to clinically distinguish Ebola disease from other infectious diseases such as malaria, typhoid fever, shigellosis, meningitis and other viral haemorrhagic fevers because symptoms at an early stage of the disease are similar (WHO, 2025)

Confirmation that the person has an *Orthoebolavirus* infection is made using the following diagnostic methods:

- Reverse-transcriptase polymerase chain reaction (RT-PCR) assay
- antibody-capture enzyme-linked immunosorbent assay (ELISA)
- antigen-capture detection tests
- virus isolation by cell culture.

Samples collected from patients are an extreme biohazard risk; laboratory testing on non-inactivated samples should be conducted under maximum biological containment conditions (WHO, 2025).

The World Health Organization (WHO) has published case definitions for EVD, infection prevention and control research priorities in health care settings and infection prevention and control guidelines for Ebola and Marburg disease (WHO, 2014; 2023a; 2024).

Animal

Ebola viruses are transmitted to people from wild animals such as fruit bats, porcupines and non-human primates (AFRO, no date). Preventing Ebola outbreaks is challenging because the "reservoir hosts" of the viruses that cause the disease are not known. Africa's great apes, gorillas and chimpanzees have been sources of human infection, however, high case fatality rates among apes suggest

they are not maintenance reservoir hosts. Wildlife mortality events during EVD outbreaks have involved other mammals including monkeys, pigs, and antelope. Pigs, monkeys, and bats are all implicated as hosts (Hayman, 2019). Scientists believe African fruit bats are involved in the spread of *orthoebolaviruses*. These fruit bats may be the source of the virus. Infected animals can spread the virus to other animals through contact with infected body fluids or items contaminated by these fluids (CDC, 2024).

Metrics and numeric limits

The 2014-2016 epidemic in West Africa was the largest Ebola outbreak since the virus was first discovered in 1976. A total of 28,616 Ebola cases were reported in Guinea, Liberia and Sierra Leone, with 11,310 deaths (WHO, 2016a).

The 2018-2020 EVD outbreak in Congo DRC was the second largest on record with a total of 3481 cases (3323 confirmed, 158 probable) reported, including 2299 fatalities (WHO, 2020a).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

United Nations. 2023. UN Recommendations on the Transport of Dangerous Goods - UN Model Regulations. (UNECE, 2023)

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: It is thought that fruit bats of the Pteropodidae family are natural Ebola virus hosts. Ebola is introduced into the human population through close contact with the blood, secretions, organs or other bodily fluids of infected animals such as fruit bats, chimpanzees, gorillas, monkeys, forest antelope or porcupines found ill or dead or in the rainforest (WHO, 2023a).

Ebola then spreads through human-to-human transmission via direct contact (through broken skin or mucous membranes) with blood or body fluids of a person who is sick with or has died from Ebola, or objects that have been contaminated with body fluids (such as blood, faeces, vomit) from a person sick with Ebola or the body of a person who died from Ebola (WHO, 2023a).

Health-care workers have frequently been infected while treating patients with suspected or confirmed EVD. This occurs through close contact with patients when infection control precautions are not strictly practised. Burial ceremonies that involve direct contact with the body of the deceased can also contribute to the transmission of Ebola. People remain infectious as long as their blood contains the virus. After recovery, there is the possibility of sexual transmission, which can be reduced with support and information for survivors (WHO, 2023a).

Pregnant women who get acute Ebola and recover from the disease may still carry the virus in breastmilk, or in pregnancy-related fluids and tissues. This poses a risk of transmission to the baby they carry, and to others. Women who become pregnant after surviving Ebola disease are not at risk of carrying the virus.

Impacts: The symptoms of Ebola disease can be sudden and include fever, fatigue, malaise, muscle pain, headache and sore throat. These are followed by vomiting, diarrhoea, abdominal pain rash, and symptoms of impaired kidney and liver functions. It is important for health and care workers to be on the lookout for these symptoms. Despite a perception that bleeding is a common symptom, this is less frequent and can occur later in the disease. Some patients may develop internal and external bleeding, including blood in vomit and faeces, bleeding from the nose, gums and vagina. Bleeding at the sites where needles have punctured the skin can also occur. The impact on the central nervous system can result in confusion, irritability and aggression (WHO, 2025).

After recovering from Ebola, some people may have symptoms for two years or longer. These symptoms can include, feeling tired, headache, muscle and joint pain, eye pain and vision problems, weight gain, belly pain and loss of appetite, hair loss and skin problems, trouble sleeping, memory loss, hearing loss, depression and anxiety (WHO, 2023a).

Rivera & Massoudi (2016), in their review of EBOV pathogenesis, current vaccine and therapeutic candidates, and mechanisms of viral persistence and long-term health sequelae for Ebola disease survivors, reported that the virus pathogenesis has identified that the virus initially and preferentially infects monocytes, macrophages impairs leading to the robust expression of inflammatory mediators. However, fundamental questions still remain, about how Ebola disables innate immunity (Rivera & Massoudi, 2016)

Multi-hazard Context: Not applicable.

Monitoring: The section and the table below offer an overview of monitoring for Ebola. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	WHO
How is the Hazard Observed/Monitored/Forecast?	FAO empres-i+ https://empres-i.apps.fao.org/diseases

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar,

Preliminary – Corrections Pending

countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a disaster from natural hazards. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023b).

Risk Management: People with symptoms of Ebola should get medical care immediately. Early care improves a person's chances of surviving Ebola. It is not safe to care for people with Ebola at home, because the person may make other people sick. At home, they will not receive the same level of care they can get from professionals. Simple interventions early on can significantly improve chances of survival. This includes rehydration with fluids and body salts (given orally or intravenously), and treatment of specific symptoms such as low blood pressure, vomiting, diarrhoea and infections. WHO has made strong recommendations for the use of two monoclonal antibody treatments in treating Ebola: mAb114 (Ansuvimab; Ebanga) and REGN-EB3 (Inmazeb). (WHO, 2025).

Community engagement is key to successfully controlling outbreaks. Working with communities to reduce risk factors for Ebola transmission is critical to controlling outbreaks. Burial ceremonies that involve direct contact with the body of the deceased can contribute to the transmission of Ebola (WHO, 2025).

Good outbreak control relies on applying a package of interventions, including case management, surveillance and contact tracing, a good laboratory service, safe burials and social mobilisation. Community engagement is key to successfully controlling outbreaks. Raising awareness of risk factors for Ebola infection and protective measures (including vaccination) that individuals can take is an effective way to reduce human transmission. Risk reduction messaging should focus on several factors: reducing the risk of wildlife-to-human transmission; reducing the risk of human-to-human transmission; outbreak containment measures; reducing the risk of possible sexual transmission; reducing the risk of transmission from pregnancy-related fluids and tissue; and controlling infection in health-care settings (WHO, 2025).

Ervebo was licensed in November 2019 by the European Medicines Agency and prequalified by WHO. The United States Food and Drug Administration licensed the vaccine in December 2019. Since then, Burundi, Central African Republic, the Democratic Republic of Congo, Ghana, Guinea, Rwanda, Uganda and Zambia have also approved the vaccine. The vaccine is safe and protective against the species Zaire ebolavirus. It is recommended by the Strategic Advisory Group of Experts (SAGE) on Immunization as part as a broader set of Ebola outbreak response tools (WHO, 2020b).

In May 2020, the European Medicines Agency recommended granting marketing authorisation to a second new vaccine delivered in 2 doses called Zabdeno (Ad26.ZEBOV) and Mvabea (MVA-BN-Filo) for individuals 1 year and older. The vaccine is delivered in 2 doses: Zabdeno is administered first and Mvabea is given approximately 8 weeks later as a second dose. This prophylactic 2-dose regimen is therefore not suitable for an outbreak response where immediate protection is necessary. For individuals at imminent risk of exposure to Ebola (for example, health care professionals and those living in or visiting areas with an ongoing Ebola virus disease outbreak) who completed the Zabdeno and Mvabea 2-dose vaccination regimen, a Zabdeno booster vaccination should be considered if more than 4 months have passed since the second dose was administered (WHO, 2020b).

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WHO, 2020b. Ebola virus disease: Vaccines. World Health Organization (WHO). https://www.who.int/news-room/questions-and-answers/item/ebola-vaccines Accessed 18 January 2025.

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0210 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Escherichia coli (STEC) (Human)

Definition

Escherichia coli (*E. coli*) is a bacterium commonly found in the gut. Some strains can cause serious food poisoning, leading to diarrhoea and sometimes to life-threatening complications including haemolytic uraemic syndrome (WHO, 2018a).

Reference

WHO, 2018a. E. coli. World Health Organization (WHO). https://www.who.int/news-room/fact-sheets/detail/e-coli Accessed 15 February 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Shiga-toxin-producing *E. coli* (STEC), Verocytotoxigenic *E. coli* (VTEC), Enterohaemorrhagic *E. coli* (EHEC).

Additional scientific description

Most strains of *E. coli* are harmless and are commonly found in the lower intestinal tract of humans and warm-blooded animals. Some strains however, such as Shiga-toxin producing *E. coli* (STEC), are harmful and can lead to serious foodborne infections. *E. coli* O157:H7 is the most important STEC serotype in relation to public health, although other serotypes have often been involved in sporadic cases and outbreaks (WHO, 2018a).

STEC transmission is faecal-oral, with cattle the main reservoir although sheep and goats also carry Enterohaemorrhagic E. coli (EHEC). It is transmitted to humans primarily through the consumption of contaminated water and foods, including raw or undercooked ground meat products (such as hamburgers or dried cured salami), raw milk (such as cheese or yoghurt made from raw milk), and vegetables contaminated with faeces. Contact with animals (e.g., farms and petting zoos) is also a transmission route (WHO, 2018a).

Humans are a secondary but significant reservoir for EHEC. People can be asymptomatic carriers of the pathogen (and therefore show no clinical signs of disease) but are capable of infecting others (WHO, 2018a).

Symptoms are usually self-limiting, with recovery within ten days of onset. They include abdominal cramps, diarrhoea which may be bloody (haemorrhagic colitis), fever and vomiting. In a small proportion of patients (particularly young children and the elderly), the infection may lead to haemolytic uraemic syndrome (HUS) which can be life-threatening and is characterised by acute renal failure, haemolytic anaemia and thrombocytopenia (low blood platelets) (WHO, 2018a).

It is estimated that up to 10% of patients with STEC infection may develop HUS, with a case-fatality rate ranging from 3 to 5%. Overall, HUS is the most common cause of acute renal failure in young children. It can cause neurological complications (such as seizure, stroke and coma) in 25% of HUS patients and chronic renal sequelae, usually mild, in around 50% of survivors (WHO, 2018a).

Antibiotics are not recommended for the treatment of EHEC infections because antibiotics can exacerbate the complications of EHEC, leading to HUS. In addition, many strains are multiply resistant to antibiotics such as ampicillin, streptomycin, trimethoprim, sulphonamide and tetracycline (Tadesse et al., 2012).

Laboratory diagnosis is via isolation of the organism on culture and / or detection of the toxin gene in faeces (ECDC, 2018).

The European Centre for Disease Prevention and Control (ECDC) has published case classification for outbreak management and national epidemiological surveillance (ECDC, 2018).

Metrics and numeric limits

In 2015, WHO published the first estimates of the global burden of foodborne disease, which estimated that in 2010 more than 600

million people fell ill from foodborne disease caused by 31 microbiological and chemical agents (including STEC), resulting in 420 000 deaths and 33 million Disability Adjusted Life Years (DALYs). The Foodborne Disease Burden Epidemiology Reference Group (FERG), which conducted the work for WHO, estimated that foodborne STEC caused more than 1 million illnesses, resulting in more than 100 deaths and nearly 13,000 DALYs (FAO & WHO, 2018).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers include infection, underlying malnutrition, water contamination and other causes such as poor personal hygiene (WHO, 2924). In summary, these are described below:

- ***Infection***: Diarrhoea is a symptom of E, coli and is spread by faeces-contaminated water. Infection is more common when there is a shortage of adequate sanitation and hygiene and safe water for drinking, cooking and cleaning. Among children under 5 years of age, the most common viral pathogens are rotavirus, norovirus, adenovirus and astrovirus. (WHO, 2024a).
- ***Malnutrition***: Children who die from diarrhoea often suffer from underlying malnutrition, which makes them more vulnerable to diarrhoea. Each diarrhoeal episode, in turn, makes their malnutrition even worse. Diarrhoea is a leading cause of malnutrition in children under 5 years old (WHO, 2024a).
- ***Source***: Water contaminated with human faeces, for example from sewage, septic tanks and latrines, is of particular concern. Animal faeces also contain microorganisms that can cause diarrhoea (WHO, 2024a).
- ***Other causes***: Diarrhoeal disease can also spread from person-to-person, aggravated by poor personal hygiene. Food is another major cause of diarrhoea when it is prepared or stored in unhygienic conditions. Unsafe domestic water storage and handling is also an important risk factor. Fish and seafood from polluted water may also contribute to the disease (WHO, 2024a).

Most available information on STEC relates to serotype O157:H7, since it is easily differentiated biochemically from other *E. coli* strains. The reservoir of this pathogen appears to be mainly cattle. In addition, other ruminants such as sheep, goats and deer are considered significant reservoirs, while other mammals (such as pigs, horses, rabbits, dogs, and cats) and birds (such as chickens and turkeys) have been found infected (WHO, 2018a).

E. coli O157:H7 is transmitted to humans primarily through consumption of contaminated foods, such as raw or undercooked ground meat products and raw milk. Faecal contamination of water and other foods, as well as cross-contamination during food preparation (with beef and other meat products, contaminated surfaces and kitchen utensils), will also lead to infection. Examples of foods implicated in outbreaks of *E. coli* O157:H7 include undercooked hamburgers, dried cured salami, unpasteurized fresh-pressed apple cider, yoghurt, and cheese made from raw milk (WHO, 2018a).

An increasing number of outbreaks are associated with the consumption of fruits and vegetables (including sprouts, spinach, lettuce, coleslaw, and salad) whereby contamination may be due to contact with faeces from domestic or wild animals at some stage during cultivation or handling. STEC has also been isolated from bodies of water (such as ponds and streams), wells and water troughs, and has been found to survive for months in manure and water-trough sediments. Waterborne transmission has been reported, both from contaminated drinking water and from recreational waters (WHO, 2018a).

Impacts: The most severe threat posed by diarrhoea is dehydration. During a diarrhoeal episode, water and electrolytes (sodium, chloride, potassium and bicarbonate) are lost through liquid stools, vomit, sweat, urine and breathing (WHO, 2024a). Dehydration occurs when these losses are not replaced.

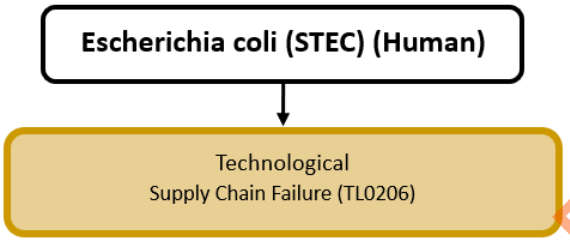
WHO (2024a) describes the degree of dehydration as rated on a scale of 3.

- severe dehydration (at least two of the following signs):
  - lethargy/unconsciousness
  - sunken eyes
  - unable to drink or drink poorly
  - skin pinch goes back very slowly (≥2 seconds)
- some dehydration (two or more of the following signs):
  - restlessness, irritability
  - sunken eyes
  - drinks eagerly, thirsty
- no dehydration (not enough signs to classify as some or severe dehydration)

Preliminary – Corrections Pending

Escherichia coli (*E. coli*) is a bacterium that is commonly found in the gut of humans and warm-blooded animals. Most strains of E. coli are harmless. STEC produces toxins, known as Shiga-toxins because of their similarity to the toxins produced by *Shigella dysenteriae*. STEC can grow in temperatures ranging from 7 °C to 50 °C, with an optimum temperature of 37 °C. Some STEC can grow in acidic foods, down to a pH of 4.4, and in foods with a minimum water activity (aW) of 0.95. STEC is destroyed by thorough cooking of foods until all parts reach a temperature of 70 °C or higher. *E. coli* O157:H7 is the most important STEC serotype in relation to public health; however, other serotypes have frequently been involved in sporadic cases and outbreaks (WHO, 2018a).

Multi-hazard Context: The figure below summarises common interactions between *Escherichia coli* (STEC) and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: Surveillance for disease outbreaks with timely and detailed investigation is essential. The WHO supports the coordination of information sharing through the International Health Regulations (WHO, 2016), the International Food Safety Authority Network (INFOSAN) and other reporting mechanisms; it is monitoring the outbreaks of E. coli O104:H4 infection and providing the latest information. The WHO is working closely with national health authorities and international partners to detect the unusual bacterial strain and track down its source (WHO, 2018a).

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date).

Risk Management: In partnership with surveillance and rapid response, prevention is key.

- STEC is heat-sensitive. Following the WHO 'Five keys to safer food' is a key measure to prevent infections with foodborne pathogens such as STEC in households and restaurants (WHO, 2006).
- Similar to other faecal oral pathogens, safe water management, including protecting water sources from faecal contamination and safely storing and treating water at home, is important for prevention. Water treatment technologies should meet WHO standards for performance. Use of latrines and toilets that safely separate excreta from human contact and safely manage faecal waste including through safe containment, transport and treatment, are important measures for preventing contamination of the environment. It is particularly important that health-care facilities treating EHEC patients have basic water, sanitation and hygiene services (WHO, 2008; 2018a; b; 2019).
- The long-term prevention of infection requires control measures at all stages of the food chain, from agricultural production on the farm to processing, manufacturing and preparation of foods in both commercial establishments and household kitchens (WHO, 2019).

Preliminary – Corrections Pending

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Coordinating agency or organisation

World Health Organization

Preliminary – Corrections Pending

BI0211 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Hepatitis A (Human)

Definition

Hepatitis A is an acute vaccine-preventable viral liver disease and can cause mild to severe illness. Hepatitis A occurs sporadically and in epidemics worldwide, with a tendency for cyclic recurrences, as the virus persists in the environment and can withstand food production processes routinely used to inactivate or control bacterial pathogens. (WHO, 2025a).

Reference

WHO, 2025a. Hepatitis A. World Health Organization (WHO). www.who.int/news-room/fact-sheets/detail/hepatitis-a https://www.who.int/news-room/fact-sheets/detail/hepatitis-a Accessed 25 February 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

HAV

Additional scientific description

Almost everyone recovers fully from hepatitis A with lifelong immunity. However, a very small proportion of people infected with hepatitis A could die from fulminant hepatitis. The risk of hepatitis A infection is associated with a lack of safe water and poor sanitation and hygiene (such as contaminated and dirty hands). A safe and effective vaccine is available to prevent hepatitis A (WHO, 2025a).

Hepatitis A is an inflammation of the liver caused by the hepatitis A virus (HAV). The virus is primarily spread when an uninfected (and unvaccinated) person ingests food or water that is contaminated with the faeces of an infected person. The disease is closely associated with unsafe water or food, inadequate sanitation, poor personal hygiene and oral-anal sex (WHO, 2025a).

Unlike hepatitis B and C, hepatitis A does not cause chronic liver disease, but it can cause mild to severe symptoms and rarely fulminant hepatitis (acute liver failure), which is often fatal. WHO estimates that in 2016, 7,134 persons died from hepatitis A worldwide (accounting for 0.5% of the mortality due to viral hepatitis) (WHO, 2025a).

Hepatitis A occurs sporadically and in epidemics worldwide, with a tendency for cyclic recurrences. Epidemics related to contaminated food or water can erupt explosively, such as the epidemic in Shanghai in 1988 that affected about 300,000 people (Wang et al, 1990). They can also be prolonged, affecting communities for months through person-to-person transmission. Hepatitis A viruses persist in the environment and can withstand food production processes routinely used to inactivate or control bacterial pathogens (WHO, 2025a).

Cases of hepatitis A are not clinically distinguishable from other types of acute viral hepatitis. Specific diagnosis is made by the detection of HAV-specific immunoglobulin G (IgM) antibodies in the blood. Additional tests include reverse transcriptase polymerase chain reaction (RT-PCR) to detect the hepatitis A virus RNA and may require specialized laboratory facilities. PCR can detect the presence of HAV infection early in the infection, even before the patient develops antibodies (IgM anti-HAV). This is particularly useful for diagnosing hepatitis A in the early stages. PCR can additionally help to monitor the progression of the infection and the resolution of infection (WHO, 2025a).

The World Health Organization (WHO) has published guidance on case classification and surveillance standards (WHO, 2018).

Metrics and numeric limits

Hepatitis A occurs sporadically and in epidemics worldwide, with a tendency for cyclic recurrences. Epidemics related to contaminated food or water can erupt explosively (WHO, 2025a).

In 2016, 7,134 persons were estimated to have died from hepatitis A worldwide (accounting for 0.5% of the mortality due to viral

hepatitis) (WHO, 2025a).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: The hepatitis A virus is transmitted primarily by the faecal-oral route; that is when an uninfected person ingests food or water that has been contaminated with the faeces of an infected person. In families, this may happen through dirty hands when an infected person prepares food for family members. Waterborne outbreaks, though infrequent, are usually associated with sewage-contaminated or inadequately treated water. The virus can also be transmitted through close physical contact (such as oral-anal sex) with an infectious person, although casual contact among people does not spread the virus (WHO, 2025a).

Anyone who has not been vaccinated or previously infected can get infected with the hepatitis A virus, and is at risk. In areas where the virus is widespread (high endemicity), most hepatitis A infections occur during early childhood (WHO 2025a) Other risk factors include:

- poor sanitation;
- lack of safe water;
- living in a household with an infected person;
- being a sexual partner of someone with acute hepatitis A infection;
- use of recreational drugs;
- sex between men; and
- travelling to areas of high endemicity without being immunized (WHO, 2025a).

Impacts: The incubation period of hepatitis A is usually 14-28 days. Symptoms of hepatitis A range from mild to severe and can include fever, malaise, loss of appetite, diarrhoea, nausea, abdominal discomfort, dark-coloured urine and jaundice (a yellowing of the eyes and skin). Not everyone who is infected will have all the symptoms. Adults have signs and symptoms of illness more often than children. The severity of disease and fatal outcomes are higher in older age groups. Infected children under 6 years of age do not usually experience noticeable symptoms, and only 10% develop jaundice. Hepatitis A sometimes relapses, meaning the person who just recovered falls sick again with another acute episode. This is normally followed by recovery (WHO, 2025a).

Geographical distribution areas can be characterized as having high, intermediate or low levels of hepatitis A virus infection. However, infection does not always mean disease because infected young children do not experience any noticeable symptoms. Infection is common in low- and middle-income countries with poor sanitary conditions and hygienic practices, and most children (90%) have been infected with the hepatitis A virus before the age of 10 years, most often without symptoms. Infection rates are low in high-income countries with good sanitary and hygienic conditions. Disease may occur among adolescents and adults in high-risk groups, such as persons who inject drugs (PWID), men who have sex with men (MSM), people travelling to areas of high endemicity and in isolated populations, such as closed religious groups. In the United States of America, large outbreaks have been reported among persons experiencing homelessness (WHO, 2025a).

Multi-Hazard Context: Not Applicable.

Monitoring: Drinking-water surveillance is a core public health function and an integral component of the framework for safe drinking water recommended by the WHO Guidelines for drinking-water quality. It is fundamental for the delivery of safe drinking-water and protection of public health by promoting the improvement of quality, quantity, accessibility, reliability, affordability and continuity of drinking-water supplies. Risk-based drinking-water surveillance is considered best practice as it supports the development of appropriate and efficient monitoring programmes for individual supplies. It also aids prediction and identification of long-term changes and associated risks for drinking-water supply (WHO, no date h).

Risk Management: Cases of hepatitis A are not clinically distinguishable from other types of acute viral hepatitis. Specific diagnosis is made by the detection of HAV-specific immunoglobulin G (IgM) antibodies in the blood. Additional tests include reverse transcriptase polymerase chain reaction (RT-PCR) to detect the hepatitis A virus RNA and may require specialized laboratory facilities. PCR can detect the presence of HAV infection early in the infection, even before the patient develops antibodies (IgM anti-HAV). This is particularly useful for diagnosing hepatitis A in the early stages. PCR can additionally help to monitor the progression of the infection and the resolution of infection.

There is no specific antiviral treatment for hepatitis A. Instead, the management of hepatitis A focuses on supportive care to relieve symptoms and ensure adequate hydration and nutrition. Recovery from symptoms following infection may be slow and can take several weeks or months. It is important to avoid unnecessary medications that can adversely affect the liver, e.g. acetaminophen, paracetamol. Hospitalization is unnecessary in the absence of severe disease or acute liver failure. Therapy is aimed at maintaining comfort and adequate nutritional balance, including replacement of fluids that are lost from vomiting and diarrhoea.

Preliminary – Corrections Pending

Improved sanitation, food safety, safer sex practices (notably for oral-anal sex) and immunization are the most effective ways to combat hepatitis A. The spread of hepatitis A can be reduced by:

- adequate supplies of safe drinking water;
- proper disposal of sewage within communities; and
- personal hygiene practices such as regular handwashing before meals and after going to the bathroom
- use of safer sex practices – including condoms, dental dams and good hygiene practices.

Several injectable inactivated hepatitis A vaccines are available internationally. All provide similar protection from the virus and have comparable side effects. No vaccine is licensed for children younger than 1 year of age. In China, a live attenuated vaccine is also available.

Rapid detection and verification of health emergencies is essential to save lives. WHO's global surveillance system picks up public health threats 24 hours a day, 365 days a year. HAV outbreaks are regularly notified to WHO and the organization provides a coordinated 3-level response in support of its members states if necessary.

Global health sector strategies on, respectively, HIV, viral hepatitis, and sexually transmitted infections for the period 2022-2030 (GHSSs) guide the health sector in implementing strategically focused responses to achieve the goals of ending AIDS, viral hepatitis (especially chronic hepatitis B and C) and sexually transmitted infections by 2030 (WHO GHSSs, 2022).

The GHSS recommend shared and disease-specific country actions supported by actions by WHO and partners. They consider the epidemiological, technological, and contextual shifts of previous years, foster learnings across the disease areas, and create opportunities to leverage innovations and new knowledge for effective responses to the diseases. They call to scale up prevention, testing and treatment of viral hepatitis with a focus to reach populations and communities most affected and at risk for each disease, as well as addressing gaps and inequities. They promote synergies under a universal health coverage and primary health care framework and contribute to achieving the goals of the 2030 Agenda for Sustainable Development (WHO GHSSs, 2022).

WHO organizes the annual World Hepatitis Day, held on 28 July (WHO, 2025b). For World Hepatitis Day 2024, WHO focuses on the theme "It's time for action" to illustrate the urgency of scaling up viral hepatitis prevention, testing and treatment to prevent liver diseases and cancer and achieve the 2030 hepatitis elimination target (WHO, 2025b).

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0212 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Hepatitis B (Human)

Definition

Hepatitis B is a vaccine-preventable disease, that is endemic and epidemic worldwide and is caused by the Hepatitis B virus (HBV). HBV can cause both acute and chronic liver disease. Chronic infection puts people at high risk of death from cirrhosis and liver cancer (WHO, 2024).

Reference

WHO, 2024. Hepatitis B. World Health Organization (WHO). https://www.who.int/news-room/fact-sheets/detail/hepatitis-b Accessed 28 May 2025.

Annotations

Synonyms

Acute hepatitis B, Chronic hepatitis B, Hepatitis B related cirrhosis and hepatocellular carcinoma.

Additional scientific description

Hepatitis B is the most serious type of viral hepatitis. In highly endemic areas, the Hepatitis B virus (HBV), which is highly contagious, is most commonly spread from mother to child at birth (perinatal transmission), or through horizontal transmission (exposure to infected blood), especially from an infected child to an uninfected child during the first five years of life (WHO, 2016a).

The incubation period of the HBV is 75 days on average but can vary from 30 to 180 days. Most people do not experience any symptoms when newly infected. However, some have acute illness with symptoms that last several weeks, including yellowing of the skin and eyes (jaundice), dark urine, extreme fatigue, nausea, vomiting and abdominal pain. A small subset of persons with acute hepatitis can develop acute liver failure, which can lead to death (WHO, 2020).

In some people, the HBV can also cause a chronic liver infection that can later develop into cirrhosis (a scarring of the liver) or hepatocellular carcinoma (liver cancer). Infection in adulthood leads to chronic hepatitis in less than 5% of cases, whereas infection in infancy and early childhood leads to chronic hepatitis in about 95% of cases (WHO, 2020).

Laboratory confirmation of hepatitis B diagnosis is essential. A number of blood tests are available to diagnose and monitor people with hepatitis B. They can be used to distinguish acute and chronic infections (WHO, 2020).

The World Health Organisation (WHO) has published surveillance standards for hepatitis B (WHO, no date).

Metrics and numeric limits

Hepatitis B is a major global health problem. (WHO, 2024):

- WHO estimates that 254 million people were living with chronic hepatitis B infection in 2022, with 1.2 million new infections each year. (WHO, 2024)
- In 2022, hepatitis B resulted in an estimated 1.1 million deaths, mostly from cirrhosis and hepatocellular carcinoma (primary liver cancer). (WHO, 2024)
- The burden of infection is highest in the WHO Western Pacific Region and the WHO African Region, where 97 million and 65 million people, respectively, are chronically infected. Sixty-one million people are infected in the WHO South-East Asia Region, 15 million in the WHO Eastern Mediterranean Region, 11 million in the WHO in the WHO European Region and 5 million in the WHO Region of the Americas. (WHO, 2024)

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016b).

Preliminary – Corrections Pending

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: In highly endemic areas, hepatitis B is most commonly spread from mother to child at birth (perinatal transmission) or through horizontal transmission (exposure to infected blood), especially from an infected child to an uninfected child during the first 5 years of life. The development of chronic infection is common in infants infected from their mothers or before the age of 5 years.

Hepatitis B is also spread by needlestick injury, tattooing, piercing and exposure to infected blood and body fluids, such as saliva and menstrual, vaginal and seminal fluids. Transmission of the virus may also occur through the reuse of contaminated needles and syringes or sharp objects either in health care settings, in the community or among persons who inject drugs. Sexual transmission is more prevalent in unvaccinated persons with multiple sexual partners.

Hepatitis B infection acquired in adulthood leads to chronic hepatitis in less than 5% of cases, whereas infection in infancy and early childhood leads to chronic hepatitis in about 95% of cases. This is the basis for strengthening and prioritizing infant and childhood vaccination.

The hepatitis B virus can survive outside the body for at least 7 days. During this time, the virus can still cause infection if it enters the body of a person who is not protected by the vaccine. The virus may be detected within 30 to 60 days after infection and can persist and develop into chronic hepatitis B, especially when transmitted in infancy or childhood.

Impacts: Most people do not experience any symptoms when newly infected. Some people have acute illness with symptoms that last several weeks including yellowing of the skin and eyes (jaundice); dark urine; feeling very tired; nausea; vomiting; and pain in the abdomen.

When severe, acute hepatitis can lead to liver failure, which can lead to death. Although most people will recover from acute illness, some people with chronic hepatitis B will develop progressive liver disease and complications like cirrhosis and hepatocellular carcinoma (liver cancer). These diseases can be fatal.

As of 2022, 13% of all people estimated to be living with hepatitis B were aware of their infection, while 3% (7 million) of the people living with chronic hepatitis B were on treatment. According to the latest WHO estimates, the proportion of children under five years of age chronically infected with HBV dropped to just under 1% in 2019 down from around 5% in the pre-vaccine era ranging from the 1980s to the early 2000s.

About 1% of persons living with HBV infection (2.7 million people) are also infected with HIV. Conversely, the global prevalence of HBV infection in HIV-infected persons is 7.4%. Since 2015, WHO has recommended treatment for everyone diagnosed with HIV infection, regardless of the stage of the disease. Tenofovir, which is included in the treatment combinations recommended as first-line therapy for HIV infection, is also active against HBV (WHO, 2024).

Multi-hazard Context: Not Applicable.

Monitoring: WHO recommends that all blood donations should be screened for infections prior to use. Screening for hepatitis B, as well as hepatitis C, HIV, and syphilis, should be mandatory. Blood screening should be performed according to quality system requirements. Of the reporting countries, 10 are not able to screen all donated blood for one or more of the above infections (WHO, 2023). 99.8% of the donations in high-income countries and 99.9% in upper-middle-income countries are screened following basic quality procedures, as compared to 83% in lower-middle-income countries and 76 % in low-income countries. The prevalence of transfusion-transmissible infections in blood donations in high-income countries is considerably lower than in low- and middle-income countries (WHO, 2023).

Risk Management: It is not possible on clinical grounds to differentiate hepatitis B from hepatitis caused by other viral agents; hence laboratory confirmation of the diagnosis is essential. Several blood tests are available to diagnose and monitor people with hepatitis B. Some laboratory tests can be used to distinguish acute and chronic infections, whilst others can assess and monitor the severity of liver disease. Physical examination, ultrasound, fibroscan can also be performed to assess the degree of liver fibrosis and scarring and monitor the progression of liver disease. WHO recommends that all blood donations be tested for hepatitis B to ensure blood safety and avoid accidental transmission.

In settings with high Hepatitis B surface antigen seroprevalence in the general population (defined as ≥2% or ≥5% HBsAg seroprevalence), WHO recommends that all adults have access to and be offered HBsAg testing with linkage to prevention and care and treatment services as needed. WHO also recommends blood donor screening and routine testing for hepatitis B for all pregnant women to provide the opportunity to institute measures for the prevention of MTCT as well as focused or targeted testing of specific high-risk groups (including migrants from endemic regions, partners or family members of infected persons, and health-care workers PWID, people in prisons and other closed settings, MSM and sex workers, HIV-infected persons.

There is no specific treatment for acute hepatitis B. Chronic hepatitis B can be treated with medicines. Care for acute hepatitis B should focus on making the person comfortable. They should eat a healthy diet and drink plenty of liquids to prevent dehydration from vomiting and diarrhoea. Chronic hepatitis B infection can be treated with oral medicines, including tenofovir or entecavir. Treatment can slow the advance of cirrhosis; reduce cases of liver cancer and improve long-term survival.

Preliminary – Corrections Pending

Most people who start hepatitis B treatment must continue it for life. With the updated Hepatitis B Guidelines, it is estimated that more than 50% of people with chronic hepatitis B infection will require treatment, depending on the setting and eligibility criteria. In low-income settings, most people with liver cancer present late in the course of the disease and die within months of diagnosis. In high-income countries, patients present at the hospital earlier in the course of the disease and have access to surgery and chemotherapy, which can prolong life for several months to a few years. Liver transplantation is sometimes used in people with cirrhosis or liver cancer in technologically advanced countries, with varying success.

Hepatitis B is preventable with a vaccine. All babies should receive the hepatitis B vaccine as soon as possible after birth (within 24 hours). This is followed by two or three doses of hepatitis B vaccine at least four weeks apart. Booster vaccines are not usually required for people who have completed the three-dose vaccination series. The vaccine protects against hepatitis B for at least 20 years and probably for life. Hepatitis B can be passed from mother to child. This can be prevented by taking antiviral medicines to prevent transmission, in addition to the vaccine.

To reduce the risk of getting or spreading hepatitis B:

- practice safe sex by using condoms and reducing the number of sexual partners
- avoid sharing needles or any equipment used for injecting drugs, piercing, or tattooing
- wash your hands thoroughly with soap and water after coming into contact with blood, body fluids, or contaminated surfaces
- get a hepatitis B vaccine if working in a health-care setting.

Global health sector strategies on, respectively, HIV, viral hepatitis, and sexually transmitted infections for the period 2022-2030 guide the health sector in implementing strategically focused responses to achieve the goals of ending AIDS, viral hepatitis (especially chronic hepatitis B and C) and sexually transmitted infections by 2030 (WHO, 2022; 2024).

The GHSS recommend shared and disease-specific country actions supported by actions by WHO and partners. They consider the epidemiological, technological, and contextual shifts of previous years, foster learnings across the disease areas, and create opportunities to leverage innovations and new knowledge for effective responses to the diseases. They call to scale up prevention, testing and treatment of viral hepatitis with a focus on reaching populations and communities most affected and at risk for each disease, as well as addressing gaps and inequities. They promote synergies under a universal health coverage and primary health care framework and contribute to achieving the goals of the 2030 Agenda for Sustainable Development (WHO, 2024).

WHO organizes annual World Hepatitis Day campaigns to increase awareness and understanding of viral hepatitis. For World Hepatitis Day 2023, WHO focused on the theme “One life, one liver” to illustrate the importance of the liver for a healthy life and the need to scale up viral hepatitis prevention, testing and treatment to prevent liver diseases and achieve the 2030 hepatitis elimination target (WHO, 2024).

The WHO global guidance for country validation of viral hepatitis B and C elimination provides countries with a range of options for how to measure the targets depending on available surveillance data and capacity, as well as a checklist of other considerations to assess their progress towards elimination. These include assessing the quality of strategic information, laboratory processes, diagnostics and medicines, and health-care programmes, as well as adherence to the principles of equity, human rights and community engagement (WHO, 2021).

Preliminary – Corrections Pending

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0213 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Hepatitis C (Human)

Definition

Hepatitis C is a blood-borne liver disease caused by the hepatitis C virus: the virus can cause both acute and chronic hepatitis, ranging in severity from a mild illness lasting a few weeks to a serious, lifelong illness including liver cirrhosis and liver cancer. Hepatitis C is endemic and epidemic worldwide (WHO, 2024a).

Reference

WHO, 2024a. Hepatitis C. World Health Organization (WHO). www.who.int/news-room/fact-sheets/detail/hepatitis-c Accessed 26 May 2025.

Annotations

Synonyms

Acute hepatitis C, Chronic hepatitis C, Hepatitis C virus (HCV). Hepatitis C-related cirrhosis and liver cancer.

Additional scientific description

Hepatitis C is a viral infection that affects the liver. It can cause both acute (short-term) and chronic (long-term) illness. It can be life-threatening (WHO, 2024a).

The most common modes of infection of hepatitis C are through exposure to small quantities of blood. This may happen through injecting drug use, unsafe injection practices, unsafe health care, and transfusion of unscreened blood and blood products. Hepatitis C can also be passed from an infected mother to her baby, and via sexual practices that lead to exposure to blood; however, these modes are less common. The incubation period for hepatitis C ranges from two weeks to six months (WHO, 2024a).

Symptoms can include fever, fatigue, loss of appetite, nausea, vomiting, abdominal pain, dark urine and yellowing of the skin or eyes (jaundice) (WHO, 2024a).

There is no vaccine for hepatitis C, but it can be treated with antiviral medications. (WHO, 2024a).

Early detection and treatment can prevent serious liver damage and improve long-term health. Acute HCV infections are usually asymptomatic and most do not lead to a life-threatening disease. Around 30% (15-45%) of infected persons spontaneously clear the virus within 6 months of infection without any treatment, and the remaining 70% (55-85%) of persons will develop chronic HCV infection. Of those with chronic HCV infection, the risk of cirrhosis ranges from 15% to 30% within 20 years. (WHO, 2024a).

Hepatitis C infection is diagnosed in two steps: testing for anti-HCV antibodies with a serological test to identify people who have been infected with the virus; and, if the test is positive for anti-HCV antibodies, a nucleic acid test for HCV ribonucleic acid (RNA) to confirm chronic infection and the need for treatment. The nucleic acid test is important because about 30% of people infected with HCV spontaneously clear the infection without the need for treatment, but they will still test positive for anti-HCV antibodies (WHO, 2024a).

There are effective treatments for hepatitis C. The goal of treatment is to cure the disease and prevent long-term liver damage. Antiviral medications, including sofosbuvir and daclatasvir, are used to treat hepatitis C. WHO recommends therapy with pan-genotypic direct-acting antivirals (DAAs) for all adults, adolescents and children down to 3 years of age with chronic hepatitis C infection. People with hepatitis C may also benefit from lifestyle changes, such as avoiding alcohol and maintaining a healthy weight (WHO, 2024a).

There is no effective vaccine against hepatitis C. Prevention of hepatitis C infection depends upon reducing the risk of exposure to the hepatitis C virus (HCV) in health-care settings and in higher-risk populations, such as people who inject drugs and men who have sex with men, particularly those living with human immunodeficiency virus (HIV) infection or those who are taking pre-

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exposure prophylaxis against HIV (WHO, 2024a).

Metrics and numeric limits

Globally, an estimated 50 million people are living with chronic hepatitis C virus infection, with about 1.0 million new infections occurring per year (WHO, 2024a). However, this number may be affected by underreporting, as many new infections are asymptomatic and go undiagnosed.

The WHO estimated that in 2022, approximately 242,000 people died from hepatitis C, mostly from cirrhosis and hepatocellular carcinoma (primary liver cancer) (WHO, 2024a).

The most affected regions by hepatitis C are the WHO Eastern Mediterranean Region and the WHO European Region, with an estimated prevalence of chronic HCV infection in 2022 of 1.8% and 0.9% respectively. Prevalence of chronic hepatitis C infection in other WHO regions varies from 0.4% to 0.7%. (WHO, 2024b).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016a).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Depending on the country, HCV infection can be concentrated in certain populations. These populations include people who inject drugs, people in prisons, men who have sex with men, and HIV-infected persons. For example, an estimated 23-39% of new HCV infections occur among people who inject drugs. Globally, 1 in 3 HCV deaths are attributable to injecting drug use (WHO, no date). Yet, people who inject drugs and people in prisons are rarely included in national responses. In countries where infection control practices are or were historically insufficient, HCV infection is often more widely distributed in the general population (WHO, 2024a).

Impacts: New hepatitis C infections (approximately 80%) are usually asymptomatic. Those persons who are acutely symptomatic may exhibit fever, fatigue, decreased appetite, nausea, vomiting, abdominal pain, dark urine, grey-coloured faeces, joint pain, and jaundice (yellowing of the skin and the whites of the eyes). Around 30% (15-45%) of infected persons spontaneously clear the virus within six months of infection without any treatment. The remaining 70% (55-85%) of persons will develop chronic hepatitis C infection. Of those with chronic hepatitis C infection, a significant number will go on to develop cirrhosis (liver scarring) or liver cancer (WHO, 2024a).

WHO (2024b) reported that including Hepatitis C, about 1.3 million people died of viral hepatitis in 2022, similar to the number of deaths caused by tuberculosis. Viral hepatitis and tuberculosis were the second leading causes of death among communicable diseases in 2022, after COVID-19 (WHO, 2024b).

Multi-hazard Context: CDC in 2025 summarised the populations as being at an increased risk for hepatitis C – they include those who inject drugs or did so in the past; people with human immunodeficiency virus (HIV) infection; those with certain medical conditions, including those who have ever received maintenance haemodialysis and those with persistently abnormal alanine aminotransferase (ALT) (a liver enzyme) levels; and those who have received transfusions or organ transplants (CDC, 2025). Health-care and public safety personnel who have been exposed to the blood of someone who has hepatitis C (through needle sticks, sharps, or mucosal exposures) may be at risk of developing Hepatitis C (CDC, 2025). Infants born to people with known hepatitis C are also potentially at risk (CDC, 2025).

Monitoring: The WHO has published surveillance standards for hepatitis C (WHO, 2016b). Surveillance can help to detect outbreaks, monitor trends in incidence and identify risk factors for new infections. Many countries have laws, statutes or other regulations that mandate the reporting of cases of acute viral hepatitis C (WHO, 2016b).

The Global Health Sector Strategies (GHSS) recommend investing in strengthening information systems for viral hepatitis and integrating them more fully into broader health information systems (WHO, 2022).

WHO supports countries to conduct all-hazards strategic risk assessments in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date).

Risk Management: Early diagnosis can prevent health problems that may result from infection and can prevent transmission of the virus. The WHO recommends testing people who may be at increased risk of infection. Ways to prevent hepatitis C include safe handling and disposal of needles and medical waste, harm-reduction services for people who inject drugs, testing of donated

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blood for HCV, training of health personnel, and practicing safe sex by using barrier methods such as condoms (WHO, 2024a).

Direct-acting antiviral medicines (DAAs) can cure more than 95% of persons with hepatitis C infection, but access to diagnosis and treatment is low (WHO, 2024a).

In 2018, the WHO updated its guidelines for the care and treatment of persons diagnosed with chronic HCV infection. These guidelines are intended for government officials to use as the basis for developing national hepatitis policies, plans and treatment guidelines (WHO, 2018).

The Global Health Sector Strategies (GHSS) on, respectively, HIV, viral hepatitis, and sexually transmitted infections for the period 2022-2030 guide the health sector in implementing strategically focused responses to achieve the goals of ending AIDS, viral hepatitis (especially chronic hepatitis B and C) and sexually transmitted infections by 2030 (WHO, 2022).

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0214 / BIOLOGICAL / Infectious Diseases (Human and Animal)

HIV and AIDS (Human)

Definition

Human immunodeficiency virus (HIV) is a virus that attacks the body's immune system. Acquired immunodeficiency syndrome (AIDS) occurs at the most advanced stage of infection. HIV targets the body's white blood cells, weakening the immune system. This makes it easier to get sick with diseases like tuberculosis, infections and some cancers. HIV is spread from the body fluids of an infected person, including blood, breast milk, semen and vaginal fluids. WHO now defines Advanced HIV Disease (AHD) as CD4 cell count less than 200 cells/mm3 or WHO stage 3 or 4 in adults and adolescents. All children younger than 5 years of age living with HIV are considered to have advanced HIV disease (WHO, 2024a).

Reference

WHO, 2024a. HIV/AIDS. World Health Organization (WHO). https://www.who.int/news-room/fact-sheets/detail/hiv-aids Accessed 13 February 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Acquired immunodeficiency syndrome. AIDS. Human immunodeficiency virus. HIV

Additional scientific description

HIV remains a major global public health issue, having claimed an estimated 42.3 million lives to date. Transmission is ongoing in all countries globally (WHO, 2024a). There were an estimated 39.9 million people living with HIV at the end of 2023, 65% of whom are in the WHO African Region. In 2023, an estimated 630 000 people died from HIV-related causes and an estimated 1.3 million people acquired HIV (WHO, 2024a).

There is no cure for HIV infection. However, with access to effective HIV prevention, diagnosis, treatment and care, including for opportunistic infections, HIV infection has become a manageable chronic health condition, enabling people living with HIV to lead long and healthy lives (WHO, 2024a).

WHO, the Global Fund and UNAIDS all have global HIV strategies that are aligned with the SDG target 3.3 of ending the HIV epidemic by 2030 (WHO, 2024a).

By 2025, 95% of all people living with HIV should have a diagnosis, 95% of whom should be taking lifesaving antiretroviral treatment, and 95% of people living with HIV on treatment should achieve a suppressed viral load for the benefit of the person's health and for reducing onward HIV transmission. In 2023, these percentages were 86%, 89%, and 93% respectively (WHO, 2024a).

In 2023, of all people living with HIV, 86% knew their status, 77% were receiving antiretroviral therapy and 72% had suppressed viral loads (WHO, 2024a).

Metrics and numeric limits

Global data (WHO, 2024b)

People living with HIV - An estimated 39.9 million [36.1-44.6 million] people were living with HIV at the end of 2023, of which

- 1.4 million [1.1-1.7 million] children (0-14 years old).

- 38.6 [34.9-43.1 million] adults (15+ years old).

HIV incidence - 1.3 million [1.0-1.7 million] people acquired HIV in 2023. Since 2010, the number of people acquiring HIV has been reduced by 39%, from 2.1 million [1.7-2.7 million].

- 120 000 [83 000-170 000] children acquired HIV in 2023.
- 1.2 million [950 000-1.5 million] adults acquired HIV in 2023.
- The number of people acquiring HIV decreased to 0.17 [0.13-0.21] per 1000 uninfected population in 2023 from 0.32 [0.25-0.40] in 2010.
- Since the start of the epidemic, 88.4 million [71.3 million-112.8 million] people have acquired HIV.

HIV-related mortality - In 2023, 630 000 [500 000-820 000] people died from HIV-related causes globally. Since 2010, HIV-related deaths have been reduced by 51%, from 1.3 million [1.0 million-1.7 million]. The global HIV epidemic claimed 69% fewer lives in 2023 since the peak in 2004.

- 76 000 [53 000-110 000] children died from HIV-related causes in 2023.
- 560 000 [430 000-730 000] adults died from HIV-related causes in 2023.

HIV continues to be a major global public health issue, claiming 42.3 million [35.7-51.1 million] lives so far.

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: HIV can be transmitted via the exchange of body fluids from people living with HIV, including blood, breast milk, semen, and vaginal secretions. HIV can also be transmitted to a child during pregnancy and delivery. People cannot become infected with HIV through ordinary day-to-day contact such as kissing, hugging, shaking hands, or sharing personal objects, food or water.

Behaviours and conditions that put people at greater risk of contracting HIV include:

- having anal or vaginal sex without a condom;
- having another sexually transmitted infection (STI) such as syphilis, herpes, chlamydia, gonorrhoea and bacterial vaginosis;
- harmful use of alcohol or drugs in the context of sexual behaviour;
- sharing contaminated needles, syringes and other injecting equipment, or drug solutions when injecting drugs;
- receiving unsafe injections, blood transfusions, or tissue transplantation; and
- medical procedures that involve unsterile cutting or piercing; or accidental needle stick injuries, including among health workers.

Impacts: Since the beginning of the epidemic, 88.4 million [71.3-112.8 million] people have been infected with the HIV virus and about 42.3 million [35.7-51.1 million] people have died of HIV. Globally, 39.9 million [36.1-44.6 million] people were living with HIV at the end of 2023. An estimated 0.6% [0.6-0.7%] of adults aged 15-49 years worldwide are living with HIV, although the burden of the epidemic continues to vary considerably between countries and regions. The WHO African Region remains most severely affected, with one in every 30 adults (3.4%) living with HIV and accounting for more than two-thirds of the people living with HIV worldwide (WHO, 2024c).

The symptoms of HIV vary depending on the stage of infection. HIV spreads more easily in the first few months after a person is infected, but many are unaware of their status until the later stages. In the first few weeks after being infected, people may not experience symptoms. Others may have an influenza-like illness including fever, headache, rash, and sore throat. The infection progressively weakens the immune system. This can cause other signs and symptoms swollen lymph nodes, weight loss, fever, diarrhoea and cough.

Without treatment, people living with HIV infection can also develop severe illnesses, for example, such as tuberculosis (TB), cryptococcal meningitis, severe bacterial infections and cancers such as lymphomas and Kaposi's sarcoma. HIV causes other infections to get worse, such as hepatitis C, hepatitis B and mpox.

People living with HIV who are taking anti-retroviral therapy (ART) and have an undetectable viral load will not transmit HIV to their sexual partners. Early access to ART and support to remain on treatment is therefore critical not only to improve the health of people living with HIV but also to prevent HIV transmission.

Multi-hazard Context: Multi-hazard consequences include tuberculosis (TB), cryptococcal meningitis, severe bacterial infections and cancers such as lymphomas and Kaposi's sarcoma. HIV causes other infections to get worse, such as hepatitis C, hepatitis B and mpox.

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Monitoring: Global health sector strategies on HIV, viral hepatitis, and sexually transmitted infections for the period 2022-2030 guide strategic responses to achieve the goals of ending AIDS, viral hepatitis B and C, and sexually transmitted infections by 2030.

WHO's Global HIV, Hepatitis and STIs Programmes recommend shared and disease-specific country actions supported by WHO and partners. They consider the epidemiological, technological, and contextual shifts of previous years, foster learning, and create opportunities to leverage innovation and new knowledge.

WHO's programmes call to reach the people most affected and most at risk for each disease, and to address inequities. Under a framework of universal health coverage and primary health care, WHO's programmes contribute to achieving the goals of the 2030 Agenda for Sustainable Development.

The Global Health Observatory (GHO) data repository is WHO's gateway to health-related statistics for its 194 Member States. It provides access to over 1000 indicators on priority health topics including mortality and burden of diseases, the Millennium Development Goals (child nutrition, child health, maternal and reproductive health, immunization, HIV/AIDS, tuberculosis, malaria, neglected diseases, water and sanitation), non-communicable diseases and risk factors, epidemic-prone diseases, health systems, environmental health, violence and injuries, equity among others (WHO, 2024c).

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country's risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date).

Risk Management: HIV can be diagnosed through rapid diagnostic tests that provide same-day results. This greatly facilitates early diagnosis and linkage with treatment and prevention. People can also use HIV self-tests to test themselves. However, no single test can provide a full HIV-positive diagnosis; confirmatory testing is required, conducted by a qualified and trained health worker or community worker. HIV infection can be detected with great accuracy using WHO-prequalified tests within a nationally approved testing strategy and algorithm.

Most widely used HIV diagnostic tests detect antibodies produced by a person as part of their immune response to fight HIV. In most cases, people develop antibodies to HIV within 28 days of infection. During this time, people are in the so-called "window period" when they have low levels of antibodies which cannot be detected by many rapid tests, but they may still transmit HIV to others. People who have had a recent high-risk exposure and test negative can have a further test after 28 days.

Following a positive diagnosis, people should be retested before they are enrolled in treatment and care to rule out any potential testing or reporting errors. While testing for adolescents and adults has been made simple and efficient, this is not the case for babies born to HIV-positive mothers. For children less than 18 months of age, rapid antibody testing is not sufficient to identify HIV infection – virological testing must be provided as early as birth or at 6 weeks of age. New technologies are now available to perform this test at the point of care and enable same-day results, which accelerate appropriate linkage with treatment and care.

HIV is a preventable disease. Reduce the risk of HIV infection by:

- using a male or female condom during sex
- being tested for HIV and sexually transmitted infections
- having a voluntary medical male circumcision
- using harm reduction services for people who inject and use drugs.

People taking antiretroviral therapy (ART) and who have no evidence of the virus in their blood will not pass HIV to their sexual partners. Access to testing and ART is an important part of preventing HIV.

Antiretroviral drugs given to people without HIV can prevent infection. When given before possible exposure to HIV it is called pre-exposure prophylaxis (PrEP) and when given after exposure it is called post-exposure prophylaxis (PEP). People can use PrEP or PEP when the risk of contracting HIV is high; people should seek advice from a clinician when thinking about using PrEP or PEP.

There is no cure for HIV infection. It is treated with antiretroviral drugs, which stop the virus from replicating in the body.

Current antiretroviral therapy (ART) does not cure HIV infection but allows a person's immune system to get stronger. This helps them to fight other infections. Currently, ART must be taken every day for the rest of a person's life. ART lowers the amount of the virus in a person's body. This stops symptoms and allows people to live full and healthy lives. People living with HIV who are taking ART and who have no evidence of the virus in their blood will not spread the virus to their sexual partners.

Pregnant women with HIV should have access to, and take, ART as soon as possible. This protects the health of the mother and

Preliminary – Corrections Pending

will help prevent HIV transmission to the foetus before birth, or through breast milk.

Advanced HIV disease remains a persistent problem in the HIV response. WHO is supporting countries to implement the advanced HIV disease package of care to reduce illness and death. Newer HIV medicines and short-course treatments for opportunistic infections like cryptococcal meningitis are being developed that may change the way people take ART and prevention medicines, including access to injectable formulations, in the future.

Testing, treatment and viral load suppression cascades among all people living with HIV.

By 2025, 95% of people living with HIV should know their HIV status (first 95)

- In 2023, 86% [69->98%] of people living with HIV knew their status.
- To reach the first 95-95-95 target, an additional 3.4 million people living with HIV need to be made aware of their HIV status.

People living with HIV receiving antiretroviral therapy (second 90)

- In 2023, 77% [61-89%] of people living with HIV were receiving antiretroviral therapy.
- To reach the second 95-90-86 testing, treatment and viral load suppression cascade target, an additional 5.4 million people living with HIV need to know their status and access antiretroviral therapy.

People living with HIV with suppressed viral loads (third 86)

- In 2023, 72% [65-80%] of people living with HIV had suppressed viral loads.
- To reach the third 95-90-86 testing, treatment and viral load suppression cascade target, an additional 5.6 million people living with HIV need to know their status, access antiretroviral therapy, and have viral load suppression.

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Coordinating agency or organisation

World Health Organization (WHO), Joint United Nations Programme on HIV/AIDS (UNAIDS).

Preliminary – Corrections Pending

BI0215 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Lassa Fever (Human)

Definition

Lassa fever is a zoonotic disease associated with acute and potentially fatal haemorrhagic illness caused by Lassa virus. The virus is a single-stranded RNA virus belonging to the virus family Arenaviridae. About 1 in 5 infections result in severe disease, where the virus affects several organs such as the liver, spleen and kidneys. (WHO, 2024a).

Reference

WHO, 2024a. Lassa fever. World Health Organization (WHO). www.who.int/news-room/fact-sheets/detail/lassa-fever Accessed 6 January 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Lassa hemorrhagic fever.

Additional scientific description

Although first described in the 1950s, the virus causing Lassa disease was not identified until 1969. Lassa fever is a zoonotic disease, meaning that humans become infected from contact with infected animals. The animal reservoir, or host, of Lassa virus is a rodent of the genus Mastomys, commonly known as the 'multimammate rat'. Mastomys rats infected with Lassa virus do not become ill but can shed the virus in their urine and faeces (WHO, 2024a). People at greatest risk are those living in rural areas where Mastomys are usually found, especially in communities with poor sanitation or crowded living conditions. Lassa fever occurs in all age groups and both sexes.

About 80% of people who become infected with Lassa virus have no symptoms. One in five infections results in severe disease, where the virus affects several organs such as the liver, spleen and kidneys. Because the clinical course of the disease is so variable, detection of the disease in affected patients has been difficult. When the disease is confirmed to be present in a community, however, prompt isolation of affected patients, good infection prevention and control practices, and rigorous contact tracing can stop outbreaks (WHO, 2024a).

Lassa fever is difficult to diagnose because the symptoms are non-specific. Definitive diagnosis requires viral and serological testing available only in reference laboratories. Isolation of the virus is usually done from blood, urine or throat washings (WHO, 2024a).

Lassa fever can cause prolonged epidemics and is endemic in Benin, Ghana, Guinea, Liberia, Mali, Sierra Leone and Nigeria (WHO, 2016a). Two recent outbreaks are summarized below:

- Liberia: Lassa fever is endemic. The World Health Organization (WHO) reported that from 1 January 2017 through 23 January 2018, 91 suspected cases were reported from six counties: Bong, Grand Bassa, Grand Kru, Lofa, Margibi, and Nimba. Thirty-three of these cases were laboratory-confirmed, including 15 deaths (case-fatality rate for confirmed cases = 45.4%) (WHO, 2018).
- Nigeria: A large outbreak of Lassa fever was reported in Nigeria in 2023, with 4702 suspected cases, five probable cases, and 877 confirmed cases between epidemiological weeks 1 and 15 of 2023 (week ending 16 April). Among confirmed cases, there were 152 deaths (CFR 17%) within the reporting period. This represented a 20% increase in confirmed cases in comparison with those reported during the same period in 2022 (733) (WHO 2023).

The Centers for Disease Control and Prevention has published information on case definitions and classification for viral haemorrhagic fevers (CDC, 2024).

The WHO has published recommendations for prevention and control (WHO, 2024a).

Research conducted in domestic and non-domestic animals (in Birds, lizards, and domestic mammals [dogs, pigs, cattle and goats]) from 2021-2022 in southern Nigeria showed lizards had the highest positivity rate by PCR and seropositivity was highest among cattle (Happi et al., 2023).

Metrics and numeric limits

Although approximately 80% of infections are thought to be asymptomatic or mild, with symptoms including fever, headache, nausea, and vomiting, a small proportion of patients develop severe disease that can be fatal or lead to long-term sequelae such as deafness. Pregnant women in their third trimester are particularly at risk, with maternal death, adverse birth outcomes, or both, occurring in more than 80% of cases. Despite the reportedly low infection-fatality ratio, Lassa fever is one of the diseases with the highest burden among the WHO research and development priority pathogens (Doohan et al., 2024)

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Transmission is primarily from direct and indirect contact with the urine or faeces of infected Mastomys rats, usually from contaminated surfaces, food and water. Humans usually become infected with Lassa virus from exposure to urine or faeces of infected Mastomys rats. Lassa virus may also be spread between humans through direct contact with the blood, urine, faeces, or other bodily secretions of a person infected with Lassa fever. There is no epidemiological evidence supporting airborne spread between humans. Person-to-person transmission occurs in both community and health-care settings, where the virus may be spread by contaminated medical equipment, such as re-used needles. Lassa virus may persist in the semen of some males who recovered from the disease for up to a few months. However, to date, no transmission via exposure to infected semen had ever been documented (WHO, 2024a).

Impacts: The incubation period of Lassa fever ranges from 6 to 21 days. The onset of the disease, when it is symptomatic, is usually gradual, starting with fever, general weakness, and malaise. After a few days, headache, sore throat, muscle pain, chest pain, nausea, vomiting, diarrhoea, cough, and abdominal pain may follow. In severe cases, facial swelling, fluid in the lung cavity, bleeding from the mouth, nose, vagina or gastrointestinal tract and low blood pressure may develop. Shock, seizures, tremors, disorientation, and coma may be seen in the later stages. Death usually occurs within 14 days of onset in fatal cases. Deafness occurs in 25% of patients who survive the disease. In half of these cases, hearing returns partially after one to three months (WHO, 2024a).

Transient hair loss and gait disturbance may occur during recovery. During pregnancy, Lassa fever can cause high maternal and foetal mortality, especially late in pregnancy. In the third trimester, foetal death and maternal death rates can exceed 80% and 30% respectively. (WHO, 2024a).

Because the symptoms of Lassa fever are so varied and non-specific, clinical diagnosis is often difficult, especially early in the course of the disease. Lassa fever is difficult to distinguish from other viral haemorrhagic fevers such as Ebola virus disease, malaria, shigellosis, typhoid fever and yellow fever (WHO, 2024b).

Multi-hazard Context: Person-to-person transmission can also occur, particularly in health care settings lacking adequate infection prevention and control measures. The overall case fatality rate is 1% but observed case fatality rate among patients hospitalized with severe diseases of Lassa fever is 15% and above (WHO, 2024a).

The disease is closely associated with inadequate community sanitation and with unsafe water or unsafe food storage where rats have easy access. Prevention of Lassa fever relies on promoting good 'community hygiene' to discourage rodents from entering homes. Effective measures include storing grain and other foodstuffs in rodent-proof containers, disposing of garbage far from the home, maintaining clean households and keeping cats. Because Mastomys are so abundant in endemic areas, it is not possible to completely eliminate them from the environment. Family members should always be careful to avoid contact with blood and body fluids while caring for sick persons (WHO, 2024a).

Prolonged epidemics cause serious economic and social disruption (WHO, 2024a).

Monitoring: WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023b).

Preliminary – Corrections Pending

Risk Management: During an outbreak, health care professionals are at high risk of transmission, and these are associated with close contact to contaminated surfaces, sample collection, transport and laboratory investigations. In health-care settings, staff should always apply standard infection prevention and control precautions when caring for patients, regardless of their presumed diagnosis. These include basic hand hygiene, respiratory hygiene, use of personal protective equipment (to block splashes or other contact with infected materials), safe injection practices and safe burial practices. The WHO recommends standard infection prevention and control precautions (WHO, 2024a).

On rare occasions, travellers returning from endemic areas were confirmed for Lassa fever. Although malaria, typhoid fever and many other tropical infections are much more common, the diagnosis of Lassa fever should be considered in febrile patients returning from West Africa, especially if they have had exposures in areas where Lassa fever is known to be endemic. Healthcare workers seeing a patient suspected to have Lassa fever should immediately contact local and national experts for advice and to arrange for laboratory testing. (WHO, 2024a).

The Ministries of Health of Guinea, Liberia and Sierra Leone, WHO, the Office of the United States Foreign Disaster Assistance, the United Nations, and other partners have worked together to establish the Mano River Union Lassa Fever Network. The programme supports these three countries in developing national prevention strategies and enhancing laboratory diagnostics for Lassa fever and other dangerous diseases. Training in laboratory diagnosis, clinical management, and environmental control is also included (WHO, 2020).

With the WHO's overall coordination and oversight, together with a task force of internationally recognized subject-matter experts, including scientists from the most affected countries, with specific expertise in arenaviruses and in one or more research and development areas, and with support from the Wellcome Trust, the Center for Infectious Disease Research and Policy (CIDRAP) at the University of Minnesota has been tasked with facilitating the collaborative development of an "Lassa fever R&D RoadMap". The roadmap prioritizes the development of countermeasures (diagnostics, therapeutics and vaccines) that are most needed by Lassa fever-affected countries and is the result of extensive consultations with the Lassa R&D roadmap task force, leading national and international experts and other key stakeholders (WHO, 2019).

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0216 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Leprosy

Definition

Leprosy is a curable infectious disease, endemic in many countries, caused by the bacterium *Mycobacterium leprae* (*M. leprae*). It mainly affects the skin, peripheral nerves, mucosa of the upper respiratory tract and eyes. Untreated, it can lead to permanent disability (adapted from WHO, 2025).

Reference

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Preliminary – Corrections Pending

Annotations

Synonyms

Hansen's disease.

Additional scientific description

Leprosy is an age-old disease and is described in the literature of ancient civilizations. It is a chronic infectious disease which is caused by a type of bacteria called *Mycobacterium leprae*. The disease affects the skin, the peripheral nerves, mucosa of the upper respiratory tract, and the eyes. Leprosy is curable and treatment in the early stages can prevent disability. Apart from the physical deformity, persons affected by leprosy also face stigmatization and discrimination (WHO, 2025).

During 2023, a total of 182,815 new cases were reported globally, corresponding to a new case detection rate of 22.7 per million population. The number of new cases detected globally was 5% higher than in 2022 (174,094). Globally, the number of new cases decreased by 14.6% during the decade 2014-2023. The decrease in 2014-2019 was 5.3% (WHO, 2024a).

Mycobacterium leprae multiplies very slowly with an incubation period of about five years, but symptoms can take as long as 20 years to appear. If left untreated, leprosy can cause progressive and permanent damage to the skin, nerves, limbs and eyes. Leprosy is curable, and treatment provided in the early stages averts disability. Early diagnosis and treatment with multidrug therapy (MDT) remain the key elements in eliminating the disease as a public health concern. Since 1995, WHO has made MDT available free of charge to all patients worldwide (WHO, 2022).

Laboratory diagnosis is via the identification of acid-fast bacilli in a slit-skin smear. Other tests (such as serological markers) are associated with low diagnostic accuracy (WHO, 2018).

The first breakthrough for leprosy treatment occurred in the 1940s with the development of the medicine dapsone. The duration of treatment lasted many years, often a lifetime, making compliance difficult. In the 1960s, M. leprae started to develop resistance to dapsone, the only known anti-leprosy medicine at that time. In the early 1960s, rifampicin and clofazimine were discovered and found to be effective.

In 1981, the World Health Organization (WHO) recommended multidrug therapy. The currently recommended multidrug therapy regimen consists of medicines: dapsone, rifampicin and clofazimine. This treatment lasts for six months for pauci-bacillary and 12 months for multi-bacillary cases. Multidrug therapy kills the pathogen and cures the patient. Since 1995, the WHO has provided multidrug therapy for leprosy free of cost. Free multidrug therapy was initially funded by The Nippon Foundation, and since 2000 it is donated through an agreement with Novartis until at least 2020. More than 16 million leprosy patients have been treated with multidrug therapy over the past 20 years (WHO, 2025).

The Centers for Disease Control and Prevention has published information on Hansen's Disease/Leprosy case definitions (CDC, 2021).

Metrics and numeric limits

The elimination of leprosy as a public health problem is defined as a registered prevalence of less than 1 case per 10,000 population. This was achieved globally in 2000, but pockets of higher prevalence within some countries continue to persist. Based on 184,212 cases at the end of 2018, the prevalence rate corresponds to 0.2/10,000 (WHO, 2025).

Key relevant UN convention / multilateral treaty

Convention on the rights of persons with disabilities (CRPD) (UNGA, 2007).

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Leprosy is transmitted via droplets, from the nose and mouth, during close and frequent contact with untreated cases (WHO 2023a). Leprosy is a highly variable disease, affecting different people in different ways, according to their immune response. Those at one end of the spectrum, with a high level of immunity is Paucibacillary (PB) leprosy, usually manifesting as a case of leprosy with 1 to 5 skin lesions, without demonstrated presence of bacilli in a skin smear. Those with many bacilli in the body are referred to as patients with Multibacillary (MB) defined as a case of leprosy with more than five skin lesions; or with nerve involvement (pure neuritis, or any number of skin lesions and neuritis); or with the demonstrated presence of bacilli in a slit-skin smear, irrespective of the number of skin lesions (WHO, 2025).

Impacts: Leprosy is a neglected tropical disease (NTD) which still occurs in more than 120 countries, with more than 200,000 new cases reported every year. Elimination of leprosy as a public health problem globally (defined as prevalence of less than 1 per 10,000 population) was achieved in 2000 (as per World Health Assembly resolution 44.9) and in most countries by 2010 (WHO, 2025).

The reduction in the number of new cases has been gradual. As per data from 2023, Brazil, India and Indonesia continue to report more than 10,000 new cases, while 12 other countries (Bangladesh, Democratic Republic of Congo, Ethiopia, Madagascar, Mozambique, Myanmar, Nepal, Nigeria, Philippines, Somalia, Sri Lanka and the United Republic of Tanzania) each reported 1,000-10,000 new cases. Fifty-six countries reported 0 cases and 112 reported fewer than 1,000 new cases. (WHO, 2025).

Multi-hazard Context: Leprosy disproportionally affects impoverished populations with limited access to sanitation and education (Leano et al., 2019).

Stigma and discrimination against persons affected by leprosy and their families are almost as old as recorded history. Effects may include social exclusion, loss of income, reduced access to health care and education, and reduced mental well-being. Changing beliefs and prejudices is not easy. Reduction in community prejudice promotes early detection of leprosy and improves acceptance of diagnosis and adherence to treatment and self-care practices. Official processes should be in place to register and take action on reports of discriminatory behaviour. Special attention should be given to vulnerable populations including women, children, immigrants, refugees, the elderly, the homeless, residents of deprived leprosy ‘colonies’ and those living in geographically inaccessible areas (WHO SEARO, 2017).

The social, emotional and economic impacts of leprosy are arguably a greater burden than the disease itself. Persons affected by leprosy need access to mainstreamed, community-based rehabilitation services focused on mitigating the effect of impairments, enabling livelihoods and optimising inclusion in the community. Access to a country’s social entitlements and other welfare measures is also essential to reduce adverse socio-economic consequences, and to ensure appropriate care for older persons living with disabilities (WHO SEARO, 2017).

Monitoring: WHO collects relevant epidemiological and programmatic data from countries to assess the global leprosy situation and to publish an update. Annual data on leprosy are collected by WHO through a customized application with DHIS2 software (WHO, 2024a).

Risk Management: Case detection and treatment with MDT alone have proven insufficient to interrupt transmission. To boost the prevention of leprosy, with the consent of the index case, WHO recommends tracing household contacts along with neighbourhood and social contacts of each patient, accompanied by the administration of a single dose of rifampicin as preventive chemotherapy (WHO, 2025).

After detailed consultations with countries, experts, partners and persons affected by leprosy, WHO released the Towards Zero Leprosy: Global Leprosy (Hansen’s disease) Strategy 2021-2030, aligned to the neglected tropical diseases road map 2021-2030 (WHO SEARO, 2017). The Strategy calls for a vision of zero leprosy: zero infection and disease, zero disability, zero stigma and discrimination and the elimination of leprosy (defined as interruption of transmission) as its goal. The four strategic pillars of the Strategy include: implementing integrated, country-owned zero leprosy roadmaps in all endemic countries; scaling up leprosy prevention alongside integrated active case detection; managing leprosy and its complications and preventing new disability; and combatting stigma and ensuring human rights are respected. The Strategy also recognizes that global and national investment in research is essential to achieving zero leprosy and includes a set of key research priorities (WHO SEARO, 2017; WHO, 2025).

Preliminary – Corrections Pending

In 2023, WHO released technical guidance on interruption of transmission and elimination of leprosy disease. At the core of this guidance is the Leprosy Elimination Framework, which provides a clear pathway through 3 phases, i.e. interruption of transmission, elimination of leprosy disease and post-elimination surveillance, defined in terms of epidemiological milestones (WHO, 2023b).

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Coordination agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0217 / BIOLOGICAL / Infectious Diseases (Human and Animal)

zoonosis

Leptospirosis (Human and Animal)

Definition

Leptospirosis is an infectious disease caused by a pathogenic bacterium of the genus *Leptospira.* These bacteria called leptospires affect both humans and animals. Humans become infected through direct contact with the urine of infected animals or with a urine-contaminated environment which can lead to serious and sometimes fatal disease (adapted from WHO & ILS, 2003).

References

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Preliminary – Corrections Pending

Annotations

Synonyms

Weil's disease, Weil-Vasiliev disease, Swineherd's disease, rice-field fever, waterborne fever, nanukayami fever, cane-cutter fever, swamp fever, mud fever, Stuttgart disease, and Canicola fever.

Additional scientific description

Human

Leptospires are bacteria which can be either pathogenic (i.e., having the potential to cause disease in animals and humans) or saprophytic (i.e., free-living and generally considered not to cause disease (WHO SEARO, no date a).

Pathogenic leptospires are maintained in nature in the renal tubules of certain animals. Saprophytic leptospires are found in many types of wet or humid environments ranging from surface waters and moist soil to tap water. Saprophytic halophilic (salt-loving) leptospires are found in seawater (WHO & ILS, 2003).

Humans usually acquire leptospirosis through direct contact with the urine of infected animals or a urine-contaminated environment. Human-to-human transmission occurs only very rarely. The bacteria enter the body through cuts or abrasions on the skin, or the mucous membranes of the mouth, nose and eyes. (WHO, no date a).

Leptospirosis occurs worldwide but is most common in tropical and subtropical areas with high rainfall. Leptospirosis is a disease of epidemic potential, especially after heavy rainfall or flooding. Cases have been reported in most countries of the Americas and outbreaks have been reported in Brazil, Nicaragua, Guyana and several other Latin American countries. The majority of reported cases have severe manifestations, for which mortality is greater than 10%. Outbreaks can be associated with floods and hurricanes (WHO, no date b).

Animal

Leptospira is globally enzootic, but the disease is more frequently seen in warm and moist environments. Leptospira serovars are known to cause disease in mammals and have been isolated from amphibians. Some serovars have also been isolated from invertebrates, reptiles, and birds. A variety of Leptospira vaccines are available for domestic animals, including livestock. Most countries maintain a list of approved veterinary vaccines for use. For specific regulations, consult the country's veterinary authorities. Virtually all mammals are vulnerable to pathogenic Leptospira serovars to varying degrees. In incidental hosts, a serious disease with high tissue burdens and robust antibody responses can be seen (WOAH, 2020).

Metrics and numeric limits

Case-fatality rates in different parts of the world have been reported to range from <5% to 30%. These figures are not reliable because in many areas the occurrence of the disease is not well documented. In addition, mild cases may not be diagnosed as leptospirosis (WHO & ILS, 2003).

It is estimated that 0.1 to 1 per 100,000 people living in temperate climates are affected each year, with the number increasing to 10 or more per 100,000 people living in tropical climates. If there is an epidemic, the incidence can soar to 100 or more per 100,000 people. (WHO & ILS, 2003).

Cases have been reported in most countries of the Americas and outbreaks have been reported in Brazil, Nicaragua, Guyana and several other Latin American countries. The majority of reported cases have severe manifestations, for which mortality is greater than 10%. The number of human cases is not known precisely due to under- or misdiagnosis (PAHO, no date).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Driver and Impacts

Human
Hazard Drivers: Leptospirosis can also be an occupational hazard for people who work outdoors or with animals, such as rice and sugarcane field workers, farmers, sewer workers, veterinarians, dairy workers, and military personnel. It is also a recreational hazard to those who swim or wade in contaminated water (WHO, no date b). Leptospirosis is overlooked and under-reported for many reasons including difficulty in distinguishing clinical signs from those of other endemic diseases and lack of appropriate diagnostic laboratory services (WHO, 2003). **Impacts:** In the early stages of the disease, symptoms include high fever, severe headache, muscle pain, chills, redness of the eyes, abdominal pain, jaundice, haemorrhages in the skin and mucous membranes, vomiting, diarrhoea, and rash (WHO & ILS, 2003). The clinical manifestations are highly variable. Typically, the disease presents in four broad clinical categories: a mild, influenza-like illness; Weil's syndrome characterised by jaundice, renal failure, haemorrhage and myocarditis with arrhythmias; meningitis/menin-goencephalitis; and pulmonary haemorrhage with respiratory failure (Yang, 2007). Clinical diagnosis is difficult because of the varied and non-specific presentation. Confusion with other diseases, such as dengue and other haemorrhagic fevers, is particularly common in the tropics. It may present with a wide variety of clinical manifestations ranging from a mild flu-like illness to a serious and sometimes fatal disease. Icterus (jaundice) is a relatively common symptom in leptospirosis but is also found in many other diseases involving the liver such as the various forms of hepatitis (WHO SEARO, no date; WHO & ILS, 2003). Major improvements in the prognosis of severe leptospirosis have been made in recent decades, owing to the use of haemodialysis as a means of supporting the reversible renal failure that may occur in some cases and to aggressive supportive care (WHO & ILS, 2003).
Animal
Hazard Drivers: warm and moist environments, exposure to contaminated water **Impacts**: varies by serovar

Multi hazard Context: Leptospirosis is endemic in many countries, across the world. It often has a seasonal distribution, increasing with increased rainfall or higher temperature. However, the disease can occur throughout the year. High risk of exposure can be related to occupation, the environment or lifestyle choices. Epidemics may be associated with changes in human behaviour, animal or sewage contamination of water in paddy and sugarcane plantations, changes in animal reservoir density, or following natural hazards such as cyclones, hurricanes, heavy rainfall or floods. The main occupational groups at risk include farm and agricultural workers, pet shop workers, veterinarians, sewer workers, abattoir workers, meat handlers, and the military. It is also a recreational hazard to those who swim or wade in contaminated water. A variety of animal hosts have been identified, including rodents, livestock, and other domestic animals while humans serve as incidental hosts. Wild and domestic animals in the carrier state may shed leptospires intermittently for many years or even a lifetime (PAHO, no date; WHO SEARO, no date a).

Monitoring: The section and the table below offer an overview of monitoring for leptospirosis. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Ministry of Health, Ministry of Agriculture, Ministry of Livestock, FAO Reference Centres, WOAH Reference Laboratories, WHO
How is the Hazard Observed/Monitored/Forecast?	WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country's risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021). WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease

Preliminary – Corrections Pending

	surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023a). Through its global early warning system, FAO has been supporting Members with risk monitoring, assessment and forecasting for animal health threats to enhance preparedness and response to animal health threats: • The Global Animal Disease Information System, EMPRES-i+, plays a crucial role in supporting countries with early warning and early detection of animal disease outbreaks. By providing a comprehensive platform for real-time disease tracking, EMPRES-i+, enables monitoring and analysis of animal health threats effectively, collaborating closely with countries and regions on disease information sharing. This supports the dissemination of risk assessments and alerts for evidence-based decision-making. • FAO develops and maintains decision support tools that provide risk maps of existing and predicted risks of animal disease emergence, as well as other threats to the agri-food chain. • Additionally, FAO collaborates closely with international organizations like WHO and WOAH to verify disease information through integrated mechanisms such as the Epidemic Intelligence from Open Sources (EIOS), the Global Early Warning System (GLEWS+), and the World Animal Health Information System (WAHIS) for WOAH-listed diseases. These collaborations allow for the dissemination of early warning alerts and risk assessments to Members, to enable timely responses to potential outbreaks. FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

Risk Management

Human
Risk Management: During floods, leptospirosis risk increases due to contaminated floodwater containing animal urine, especially from rodents. Communication with at-risk individuals should focus on preventing contact with contaminated water, emphasizing caution during and after floods. This includes avoiding wading, swimming, or playing in floodwater, as well as avoiding contact with contaminated soil or mud (WHO, 2023b) The World Health Organization (WHO) has set several goals concerning leptospirosis: to provide estimates of the global burden of leptospirosis according to age, sex and region, to increase awareness of and commitment to the disease in developing countries; and to encourage developing countries to undertake active disease surveillance and strengthen control measures (WHO, 2011). These efforts will ultimately enable policymakers and other stakeholders to translate knowledge into policy by setting appropriate evidence-based priorities in the area of leptospirosis disease control and prevention. To coordinate and direct global research and action against human leptospirosis, the WHO has established the Leptospirosis Burden Epidemiology Reference Group (LERG). It has been assigned the following tasks: to review and appraise epidemiological evidence based on commissioned reviews and studies; to develop epidemiological tools to estimate disease burden; to estimate and express disease burden through summary measures of population health (including disability-adjusted life years); and to identify technical gaps for research (WHO, 2011). The WHO Secretariat for the LERG is based at the Department of Food Safety and Zoonoses with functions of facilitating, coordinating, guiding and monitoring the work of the LERG. The LERG also partners with other international actors including the Global Burden of Disease (GBD 2005) initiative coordinated by the Institute for Health Metrics and Evaluation (WHO, 2011).
Animal
Risk Management: biosecurity

Preliminary – Corrections Pending

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0218 / BIOLOGICAL / Infectious Diseases (Human and Animal)

zoonosis

Listeriosis (Human and Animal)

Definition

Listeriosis is a foodborne infection caused by the bacterium *Listeria monocytogenes* which can be invasive (the more serious form of the disease) or non-invasive (the milder form of the disease). Listeriosis outbreaks occur in all countries and can be a significant public health concern (WHO, 2018).

Reference

WHO, 2018. Listeriosis. World Health Organization (WHO). www.who.int/news-room/fact-sheets/detail/listeriosis Accessed 14 February 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Listeria infection.

Additional scientific description

Listeriosis is a zoonotic disease, meaning it can be transmitted from animals to humans. This is primarily due to the consumption of contaminated food, as Listeria monocytogenes, the bacterium causing listeriosis, can contaminate various food sources, including meat, dairy, and ready-to-eat foods. There are two main types of listeriosis: a non-invasive form and an invasive form.

- Non-invasive listeriosis (febrile listerial gastroenteritis) is a mild form of disease affecting mainly otherwise healthy people. Symptoms include diarrhoea, fever, headache and myalgia (muscle pain). Outbreaks have generally involved the ingestion of foods containing high doses of Listeria monocytogenes (WHO, 2018).
- Invasive listeriosis is a more severe form of the disease affecting certain high-risk groups of the population, including pregnant women, immunocompromised individuals (such as those with HIV/AIDS, leukaemia, cancer, kidney transplant and steroid therapy), elderly people and infants. This form of disease is characterised by fever, myalgia, septicaemia, meningitis, and other severe symptoms, including abortion in pregnant women. It is associated with a high mortality rate (20%-30%). The incubation period of listeriosis is usually one to two weeks but can vary from a few days up to 90 days (WHO, 2018).

Listeria monocytogenes is a highly adaptable food-borne pathogen that causes the life-threatening illness listeriosis in infected individuals. Within the host, this bacterium invades cells, escapes into the host cell cytosol and replicates intracellularly (O'Byrne & Utratna, 2010). Unlike many other common foodborne diseases causing bacteria, *L. monocytogenes* can survive and multiply at the low temperatures usually found in refrigerators. In past outbreaks, foods involved have included ready-to-eat meat products, such as frankfurters, meat spread (paté), smoked salmon and fermented raw meat sausages, as well as dairy products (including soft cheeses, unpasteurised milk and ice cream) and prepared salads (including coleslaw and bean sprouts) as well as fresh vegetables and fruit. Eating contaminated food with high numbers of *L. monocytogenes* is the main route of infection (WHO, 2018).

Infection can also be transmitted between humans, notably from pregnant women to unborn babies. Pregnant women are about 20 times more likely to contract listeriosis than other healthy adults. It can result in miscarriage or stillbirth. Newborn babies may also have low birth weight, septicaemia and meningitis. People with HIV/AIDS are at least 300 times more likely to get ill than those with a normally functioning immune system (WHO, 2018).

Owing to the long incubation period, it is challenging to identify the food which was the actual source of the infection (WHO, 2018).

In animals, *L. monocytogenes* is capable of causing septicaemia, neurologic disease, and reproductive disease in a wide range of hosts. Animals are usually asymptomatic carriers of *L. monocytogenes*. Outbreaks of listeriosis in wildlife species are typically

sporadic and associated with exposure to high burdens of the bacterium over a short period of time. Otherwise, clinical signs may arise secondary to immunocompromise, predisposing disease, or excessive environmental stress (WOAH, 2020). The clinical manifestations of listeriosis in animals include rhombencephalitis (or in some cases more disseminated encephalitic changes), septicaemia and abortion, especially in sheep, goats and cattle (WOAH, 2021).

Metrics and numeric limits

Listeriosis is a relatively rare disease with 0.1 to 10 cases per 1 million people per year depending on the countries and regions of the world. Although the number of cases of listeriosis is small, the high rate of death associated with this infection makes it a significant public health concern (WHO, 2018).

The European Centre for Disease Prevention and Control (ECDC) has published a case classification for outbreak management and national epidemiological surveillance (ECDC, 2018).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016). Codex Alimentarius (FAO & WHO, no date).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Listeriosis is a serious, but preventable and treatable disease. Pregnant women, the elderly or individuals with a weakened immune system, such as people with immuno-compromised status due to HIV, leukaemia, cancer, kidney transplant and steroid therapy, are at greatest risk of severe listeriosis and should avoid high-risk foods. High-risk foods include deli meat and ready-to-eat meat products (such as cooked, cured and/or fermented meats and sausages), soft cheeses and cold smoked fishery products. *Listeria monocytogenes* is widely distributed in nature. It can be found in soil, water, vegetation and the faeces of some animals and can contaminate foods (WHO, 2018).

Unlike many other common foodborne diseases causing bacteria, *L. monocytogenes* can survive and multiply at low temperatures usually found in refrigerators. Eating contaminated food with high numbers of *L. monocytogenes* is the main route of infection. Infection can also be transmitted between humans, notably from pregnant women to unborn babies. *L. monocytogenes* is ubiquitous in nature and found in soil, water and animal digestive tracts. Vegetables may be contaminated through soil or the use of manure as fertilizer. Ready-to-eat food can also become contaminated during processing and the bacteria can multiply to dangerous levels during distribution and storage (WHO, 2018).

L. monocytogenes are ubiquitous in nature and found in soil, water and animal digestive tracts. Vegetables may be contaminated through soil or the use of manure as fertilizer. Ready-to-eat food can also become contaminated during processing and the bacteria can multiply to dangerous levels during distribution and storage (WHO, 2018). Food most often associated with listeriosis include:

- foods with a long shelf-life under refrigeration (*L. monocytogenes*) can grow to significant numbers in food at refrigeration temperatures when given sufficient time); and
- foods that are consumed without further treatment, such as cooking, which would otherwise kill *L. monocytogenes.*

In past outbreaks, foods involved included ready-to-eat meat products, such as frankfurters, meat spread (paté), smoked salmon and fermented raw meat sausages, as well as dairy products (including soft cheeses, unpasteurized milk and ice cream) and prepared salads (including coleslaw and bean sprouts) as well as fresh vegetables and fruits (WHO, 2018).

Impacts: Pregnant women, the elderly or individuals with a weakened immune system, such as people with immuno-compromised status due to HIV, leukaemia, cancer, kidney transplant and steroid therapy, are at greatest risk of severe listeriosis and should avoid high-risk foods (WHO, 2018).

Multi-hazard Context: Not Applicable.

Monitoring: The section and the table below offer an overview of monitoring for listeriosis in animals. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Ministry of Health, Ministry of Agriculture, Ministry of Livestock, Ministry of Health, FAO Reference Centres, WOAH Reference Centres, WHO
How is the Hazard Observed/Monitored/Forecast?	WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country's risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021). WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following

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	a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date) Through its global early warning system, FAO has been supporting Members with risk monitoring, assessment and forecasting for animal health threats to enhance preparedness and response to animal health threats: • The Global Animal Disease Information System, EMPRES-i+, plays a crucial role in supporting countries with early warning and early detection of animal disease outbreaks. By providing a comprehensive platform for real-time disease tracking, EMPRES-i+, enables monitoring and analysis of animal health threats effectively, collaborating closely with countries and regions on disease information sharing. This supports the dissemination of risk assessments and alerts for evidence-based decision-making. • FAO develops and maintains decision support tools that provide risk maps of existing and predicted risks of animal disease emergence, as well as other threats to the agri-food chain. • Additionally, FAO collaborates closely with international organizations like WHO and WOAH to verify disease information through integrated mechanisms such as the Epidemic Intelligence from Open Sources (EIOS), the Global Early Warning System (GLEWS+), and the World Animal Health Information System (WAHIS) for WOAH-listed diseases. These collaborations allow for the dissemination of early warning alerts and risk assessments to Members, to enable timely responses to potential outbreaks. FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

Risk Management: The control of *Listeria monocytogenes* is required at all stages in the food chain and an integrated approach is needed to prevent the multiplication of this bacteria in the final food product (WHO, 2018). The challenges for controlling *L. monocytogenes* are considerable given its ubiquitous nature, high resistance to common preservative methods, such as the use of salt, smoke or acidic conditions in the food, and its ability to survive and grow at refrigeration temperatures (around 5 °C). All sectors of the food chain should Implement Good Hygienic Practices (GHP) and Good Manufacturing Practices (GMP) as well as implement a food safety management system based on the principles of Hazard Analysis Critical Control Points (HACCP).

The World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO) have published an international quantitative risk assessment of Listeria in ready-to-eat foods. This formed the scientific basis for the Codex Alimentarius Commission Guidelines on the Application of General Principles of Food Hygiene to the Control of *Listeria monocytogenes* in Food (FAO, 2007).

For animals, best practices indicate maintaining proper hygiene at feeding areas, especially where free-ranging ruminants are present, and preventing contamination with faeces; quaternary ammonium compounds, povidone iodine, chlorhexidine, 7.0% ethanol, glutaraldehyde, and sodium hypochlorite are typically effective; efficacy is increased if formulated with ozonated water rather than tap water (WOAH, 2020).

In general, guidance on the prevention of listeriosis is similar to guidance used to help prevent other foodborne illnesses. This includes practising safe food handling and following the WHO Five Keys to Safer Food (WHO, 2006).

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WOAH. 2021. Manual of Diagnostic Tests and Vaccines for Terrestrial Animals. Chapter 3.10.5. - Listeria monocytogenes. World Organisation https://www.woah.org/fileadmin/Home/fr/Health_standards/tahm/3.10.05_LISTERIA_MONO.pdf Accessed 25 May 2025.

Coordinating agency or organisation

World Health Organization (WHO), Food and Agricultural Organization of the United Nations (FAO), International Network of Food Safety Authorities (INFOSAN), and World Organisation for Animal Health (WOAH).

Preliminary – Corrections Pending

BI0219 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Malaria (Human)

Definition

Malaria is a life-threatening disease caused by parasites that are transmitted to people mostly through the bites of infected female Anopheles mosquitoes. In 2023, there were an estimated 263 million cases of malaria worldwide and the estimated number of malaria deaths stood at 597,000 in 83 countries (adapted from WHO, 2024a).

Reference

WHO, 2024a. Malaria. World Health Organization (WHO). www.who.int/news-room/fact-sheets/detail/malaria Accessed 26 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Ague, miasm, paludism, and jungle fever.

Additional scientific description

Malaria is caused by Plasmodium parasites. The parasites are spread to people through the bites of infected female Anopheles mosquitoes, called 'malaria vectors'. There are 5 Plasmodium parasite species that cause malaria in humans and 2 of these species - *P. falciparum* and *P. vivax* - pose the greatest threat. *P. falciparum* is the deadliest malaria parasite and the most prevalent on the African continent. P. vivax is the dominant malaria parasite in most countries outside of sub-Saharan Africa. The other malaria species which can infect humans are *P. malariae*, *P. ovale* and *P. knowlesi* (WHO, 2024a).

The WHO African Region continues to carry the heaviest burden of the disease, accounting for an estimated 94% of malaria cases worldwide in 2023. The WHO Eastern Mediterranean Region has experienced a 57% increase in incidence since 2021, rising to 17.9 cases per 1,000 population at risk in 2023. The top five countries carrying the heaviest estimated burden of malaria cases in 2023 were Nigeria (26%), the Democratic Republic of the Congo (13%), Uganda (5%), Ethiopia (4%) and Mozambique (4%). Children under 5 accounted for about 76% of all malaria deaths in the Region. In 2023, humanitarian emergencies due to conflict, violence and natural disasters disproportionately affected populations in malaria-endemic countries. Conflict and violence affected 43 endemic countries, with a total of 51.3 million internally displaced persons (IDPs) in these countries. Additionally, 22.7 million of the 37.3 million registered refugees globally originated from malaria-endemic countries (WHO, 2024a; 2024b).

Malaria is an acute febrile illness. In a non-immune individual, symptoms usually appear 10 to 15 days after the infective mosquito bite. The first symptoms – fever, headache, and chills – may be mild and difficult to recognise as malaria. If not treated within 24 hours, P. falciparum malaria can progress to severe illness, often leading to death. Children with severe malaria frequently develop one or more of the following symptoms: severe anaemia, respiratory distress in relation to metabolic acidosis, or cerebral malaria. In adults, multi-organ failure is also frequent. In malaria-endemic areas, people may develop partial immunity, allowing asymptomatic infections to occur (WHO, 2024).

Progress in global malaria control is threatened by emerging resistance to insecticides among *Anopheles* mosquitoes. However, new-generation nets, which provide better protection against malaria than pyrethroid-only nets, are becoming more widely available and represent an important tool in global efforts to combat malaria. *Anopheles stephensi* presents an added challenge for malaria control in Africa. Originally native to parts of South Asia and the Arabian Peninsula, the invasive mosquito species has been expanding its range over the last decade, with detections reported to date in eight African countries. *An. stephensi* thrives in urban settings, endures high temperatures and is resistant to many of the insecticides used in public health (WHO, 2024a; 2024b).

The WHO recommends malaria diagnosis be made using parasite-based diagnostic testing, either by microscopy (allowing visualisation of the parasite) or by malaria rapid diagnostic tests (RDT) that are genus- or species-specific. RDT has been

restricted to remote areas with limited access to good-quality microscopy services. Diagnosis of all suspected cases should be confirmed by either of these two methods before treatment, as a measure to avoid antimalarial drug resistance (WHO, 2024a).

Malaria elimination is defined as the interruption of local transmission of a specified malaria parasite species in a defined geographical area as a result of deliberate activities. Countries that have achieved at least 3 consecutive years of zero indigenous cases of malaria are eligible to apply for the WHO certification of malaria elimination. Since 2015, 15 countries have been certified by the WHO Director-General as malaria-free, including Maldives (2015), Sri Lanka (2016), Kyrgyzstan (2016), Paraguay (2018), Uzbekistan (2018), Argentina (2019), Algeria (2019), China (2021), El Salvador (2021), Azerbaijan (2023), Tajikistan (2023), Belize (2023), Cabo Verde (2024) , Egypt (2024) and Georgia (2025) (WHO, 2024a; WHO, 2025).

The World Malaria Report 2023 provides a comprehensive update on global and regional malaria data and trends. The report tracks investments in malaria programmes and research as well as progress across all intervention areas: prevention, diagnosis, treatment, elimination and surveillance. It also includes dedicated chapters on the consequences of malaria on maternal, infant and child health, the 'High burden to high impact' approach as well as biological threats to the fight against malaria. The report is based on information received from more than 80 countries and areas with ongoing malaria transmission. This is supplemented by data from national household surveys and databases held by other organizations (WHO, 2024b).

WHO has published consolidated WHO Guidelines for malaria, incorporating all of the current WHO recommendations for malaria. These are the product of careful evaluation following standardized methods as part of the WHO process for developing guidelines (WHO 2024c).

Metrics and numeric limits

Globally, in 2023, the number of malaria cases was estimated at 263 million, with an incidence of 60.4 cases per 1,000 population at risk (WHO, 2024). This is an increase of 11 million cases from the previous year and a rise in incidence from 58.6 cases per 1,000 population at risk in 2022. Globally, in 2023, the number of deaths was estimated at 597,000, with a mortality rate of 13.7 per 100,000. The number of malaria deaths and the mortality rate steadily decreased from 622,000 and 14.9 deaths per 100,000, respectively, in 2020 (WHO, 2024a).

For WHO's World Malaria Day in 2024, it was reported that 94% of all malaria cases are in the WHO African Region, 249 million, new cases of malaria in 2022 and 608 000 malaria deaths in 2022 (WHO, 2024d).

Malaria remains a significant public health challenge globally. In 2023, there were an estimated 263 million new malaria cases in 83 countries, up from 252 million in 2022 and 226 million in 2015. However, malaria control efforts have paid off. Since 2000, they have helped prevent an estimated 2.2 billion cases and 12.7 million deaths globally. In 2023 alone, more than 177 million cases and 1 million deaths were averted, the vast majority of them – 80% of cases and 94% of deaths – in Africa. The malaria burden in the WHO Eastern Mediterranean Region has surged in recent years, with an estimated 10.2 million cases reported in 2023, a 137% increase as compared to 2015. (United Nations, 2025).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Malaria mostly spreads to people through the bites of some infected female Anopheles mosquitoes. Blood transfusion and contaminated needles may also transmit malaria. The first symptoms may be mild, similar to many febrile illnesses, and are difficult to recognize as malaria. Left untreated, *P. falciparum* malaria can progress to severe illness and death within 24 hours.

Some population groups are at considerably higher risk of contracting malaria, and developing severe disease, than others. These include infants, children under 5 years of age, pregnant women and patients with HIV/AIDS, as well as non-immune migrants, mobile populations and travellers. National malaria control programmes need to take special measures to protect these population groups from malaria infection, taking into consideration their specific circumstances (WHO, 2024a).

Impacts: Globally, in 2023, the number of malaria cases was estimated at 263 million, with an incidence of 60.4 cases per 1,000 population at risk. This is an increase of 11 million cases from the previous year and a rise in incidence from 58.6 cases per 1,000 population at risk in 2022. Globally, in 2023, the number of deaths was estimated at 597,000, with a mortality rate of 13.7 per 100,000. The number of malaria deaths and the mortality rate steadily decreased from 622,000 and 14.9 deaths per 100,000, respectively, in 2020. The WHO African Region continues to carry the heaviest burden of mortality, with 95% of estimated malaria deaths worldwide (WHO, 2024).

Multi-hazard Context: Not only does malaria continue to directly endanger health and cost lives, but it also perpetuates a vicious cycle of inequity. People living in the most vulnerable situations including pregnant women, infants, children under 5 years of age, refugees, migrants, internally displaced people, and Indigenous Peoples continue to be disproportionately impacted (WHO, 2024d).

Preliminary – Corrections Pending

Displacement due to conflict, violence and disaster affects populations in situations of vulnerability, particularly in malaria-endemic regions. IDPs and refugees often face barriers to accessing health care. Women, girls and young children are among the most affected during crises, being at higher risk of malnutrition and violence, which increase their vulnerability to diseases like malaria. Natural hazards, such as floods, hurricanes and droughts, drive displacement and can disrupt malaria control efforts by damaging infrastructure and limiting access to health services (Acosta-España et al., 2024).

The malaria burden in the WHO Eastern Mediterranean Region has surged in recent years, with an estimated 10.2 million cases reported in 2023, a 137% increase as compared to 2015. WHO's Eastern Mediterranean Region comprises 21 Member States along the shore of the Mediterranean Sea, North Africa, the Horn of Africa, and parts of West and Central Asia, with a population of nearly 679 million people. African countries in this region include Djibouti, Egypt, Libya, Morocco, Somalia, Sudan and Tunisia. The alarming rise in cases has been driven by catastrophic floods in Pakistan, which led to 3.7 million additional cases between 2021 and 2023, while ongoing conflict and instability in countries such as Sudan and Yemen continue to disrupt malaria control efforts. Sudan has the highest malaria incidence rates in the Region. In 2023, more than 3.4 million cases were estimated, together with 7,900 deaths, though the figures could be higher due to underreporting as a result of the ongoing conflict and communication breakdown in Sudan (United Nations, 2025).

Faced with growing challenges, including emerging resistance to antimalarial drugs and insecticides and the impact of climate change on mosquito habitats and transmission patterns, innovative strategies are urgently needed to ensure progress towards malaria elimination (United Nations, 2025).

Monitoring: WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021b).

Malaria surveillance is the continuous and systematic collection, analysis and interpretation of malaria-related data, and the use of that data in the planning, implementation and evaluation of public health practice. Improved surveillance of malaria cases and deaths helps ministries of health determine which areas or population groups are most affected and enables countries to monitor changing disease patterns. Strong malaria surveillance systems also help countries design effective health interventions and evaluate the impact of their malaria control programmes (WHO, 2024a).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a disaster from natural hazards. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023).

Risk Management: Malaria can be prevented by avoiding mosquito bites and with medicines. Treatments can stop mild cases from getting worse (WHO, 2024 a).

Vector control is a vital component of malaria control and elimination strategies as it is highly effective in preventing infection and reducing disease transmission. The 2 core interventions are insecticide-treated nets (ITNs) and indoor residual spraying (IRS). Progress in global malaria control is threatened by emerging resistance to insecticides among Anopheles mosquitoes. However, new-generation nets, which provide better protection against malaria than pyrethroid-only nets, are becoming more widely available and represent an important tool in global efforts to combat malaria (WHO, 2024a).

Travellers to malaria-endemic areas should consult their doctor several weeks before departure. The medical professional will determine which chemoprophylaxis drugs are appropriate for the country of destination. Preventive chemotherapy is the use of medicines, either alone or in combination, to prevent malaria infections and their consequences. It requires giving a full treatment course of an antimalarial medicine to vulnerable populations at designated time points during the period of greatest malarial risk, regardless of whether the recipients are infected with malaria (WHO, 2024a).

WHO recommends malaria vaccines for the prevention of *P. falciparum* malaria in children living in areas where malaria is endemic, prioritizing areas of moderate and high transmission. Since October 2021, WHO has recommended broad use of the RTS,S/AS01 malaria vaccine among children living in regions with moderate to high *P. falciparum* malaria transmission. The vaccine has been shown to significantly reduce malaria, and deadly severe malaria, among young children. In October 2023, WHO recommended a second safe and effective malaria vaccine, R21/Matrix-M. Vaccines are now being rolled out in routine childhood immunisation programmes across Africa. Malaria vaccines in Africa are expected to save tens of thousands of young lives every year. The highest impact will be achieved, however, when the vaccines are introduced alongside a mix of other WHO-recommended malaria interventions such as bed nets and chemoprophylaxis (WHO, 2024a; 2024b).

Early diagnosis and treatment of malaria reduces disease, prevents deaths and contributes to reducing transmission. WHO recommends that all suspected cases of malaria be confirmed using parasite-based diagnostic testing (through either microscopy or a rapid diagnostic test) (WHO, 2024a).

Preliminary – Corrections Pending

Subsequent to the emergence of partial artemisinin resistance in the Greater Mekong subregion, WHO is very concerned about confirmed partial artemisinin resistance in Eritrea, Rwanda, Uganda and the United Republic of Tanzania. Based on available evidence, such resistance is also suspected in Ethiopia, Namibia, Sudan and Zambia. In 2022, WHO developed a strategy to curb antimalarial drug resistance in Africa. Regular monitoring of antimalarial drug efficacy is needed to inform treatment policies in malaria-endemic countries, and to ensure early detection of, and response to, drug resistance (WHO, 2024a).

The *Global technical strategy for malaria 2016-2030* was adopted by the World Health Assembly in May 2015. It provides a comprehensive framework to guide countries in their efforts to accelerate progress towards malaria elimination. The strategy sets the target of reducing global malaria incidence and mortality rates by at least 90% by 2030. This updated version, endorsed by the World Health Assembly in May 2021 through resolution WHA74.9, reflects lessons learned in the global malaria response over the last 5 years. While the milestones and targets remain the same, the approaches to tackling the disease, in some areas, have evolved to keep pace with the changing malaria landscape.

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0220 / BIOLOGICAL / Infectious Diseases (Human and Animal)

zoonosis

Marburg virus disease (Human and Animal)

Definition

Marburg virus disease (MVD), formerly known as Marburg haemorrhagic fever, is a severe, often fatal illness in humans. The virus causes severe viral haemorrhagic fever in humans (WHO, 2025).

Reference

WHO, 2025. Marburg virus disease. World Health Organization https://www.who.int/news-room/fact-sheets/detail/marburg-virus-disease Accessed 29 May 2025.

Preliminary – Corrections Pending

Annotations

Synonym

Marburg haemorrhagic fever. MARV, MVD.

Additional scientific description

Marburg virus (MARV) and Ravn virus (RAVV) of the species *Orthomarburgvirus marburgense* are the causative agents of Marburg virus disease (MVD). The disease has a case fatality ratio of up to 88%, but it can be much lower with good and early patient care. Both viruses are part of the Filoviridae family (filovirus) to which *Orthoebolavirus* genus belongs. Though caused by different viruses, Ebola and Marburg diseases are clinically similar. Both diseases are rare but have the capacity to cause outbreaks with high fatality rates (WHO, 2025).

Rousettus aegyptiacus bats (fruit bats) are considered natural hosts for the Marburg virus (WHO, 2025). Chimpanzees and forest antelopes are susceptible to virus replication and die from infection, they are therefore considered to be intermediate hosts (ECDC, 2024). African green monkeys (Cercopithecus aethiops) imported from Uganda were the source of infection for humans during the first Marburg outbreak (WHO, 2025).

The incubation period (interval from infection to onset of symptoms) varies from 2 to 21 days (WHO, 2025).

Although no other domestic animals have yet been confirmed as having an association with filovirus outbreaks, experimental inoculations in pigs with different Ebola viruses show that pigs are susceptible to filovirus infection and shed the virus. Therefore, pigs should be considered potential amplifier hosts during MVD outbreaks (WHO, 2025).

MVD was initially detected in 1967 after two simultaneous outbreaks in Marburg and Frankfurt in Germany and in Belgrade, Serbia. These outbreaks were associated with laboratory work using African green monkeys (Cercopithecus aethiops) imported from Uganda. Subsequently, outbreaks and sporadic cases have been reported in Angola, the Democratic Republic of the Congo, Equatorial Guinea, Ghana, Guinea, Kenya, South Africa (in a person with a recent travel history to Zimbabwe), Tanzania and Uganda. In 2008, two independent cases were reported in travellers who had visited a cave inhabited by *Rousettus aegyptiacus* bat colonies in Uganda. In September 2024, Rwanda reported the country's first outbreak and Tanzania declared another outbreak in January 2025 (WHO, 2023a; 2023b; 2025).

In animals, warning signs of infestation include Death from unknown/suspicious causes of a large number of great apes or other susceptible animals; Similar symptoms to those found in humans, particularly multiple haemorrhages and bloody discharge from the nose, mouth, and anus; and unusual animal behaviour (OIE, 2019).

Metrics and numeric limits

The World Health Organization has published guidance on case definition, clinical management and infection and control for Marburg disease and other filoviruses (WHO, 2014a; 2014b; 2016b; 2023c).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Human infection with Marburg virus disease initially results from prolonged exposure to mines or caves inhabited by Rousettus bat colonies. Once an individual is infected with the virus, Marburg can spread through human-to-human transmission via direct contact (through broken skin or mucous membranes) with the blood, secretions, organs or other bodily fluids of infected people, and with surfaces and materials (e.g. bedding, clothing) contaminated with these fluids (WHO, 2025).

Health-care workers are most at risk of being infected while treating patients with suspected or confirmed MVD. This has occurred through close contact with patients when infection control precautions are not strictly practised. Transmission via contaminated injection equipment or through needle-stick injuries is associated with more severe disease, rapid deterioration, and, possibly, a higher fatality rate. Burial ceremonies that involve direct contact with the body of the deceased can also contribute to the transmission of Marburg (WHO, 2025).

Impacts: Illness caused by Marburg virus begins abruptly, with high fever, severe headache and severe malaise. Muscle aches and pains are a common feature. Severe watery diarrhoea, abdominal pain and cramping, nausea and vomiting can begin on the third day. The appearance of patients at this phase has been described as showing “ghost-like” drawn features, deep-set eyes, expressionless faces, and extreme lethargy. Many patients develop severe haemorrhagic manifestations between 5 and 7 days, and fatal cases usually have some form of bleeding. During the severe phase of illness, patients have sustained high fevers. Involvement of the central nervous system can result in confusion, irritability, and aggression. Orchitis (inflammation of one or both testicles) has been reported occasionally in the late phase of the disease (15 days). In fatal cases, death occurs most often between 8 and 9 days after symptom onset. The average MVD case fatality rate is around 50%. Case fatality rates have varied from 24% to 88% in past outbreaks depending on virus strain and case management (WHO, 2025).

People remain infectious as long as their blood contains the virus. Relapse-symptomatic illness in the absence of re-infection in someone who has recovered from MVD is a rare event but has been documented. The reasons for this phenomenon are not yet fully understood. Marburg virus is known to persist in immune-privileged sites in some people who have recovered from Marburg virus disease. These sites include the testicles and the inside of the eye. The virus persists in the placenta, amniotic fluid and foetus in women who have been infected while pregnant and may persist in the breast milk of women infected while breastfeeding. Marburg virus transmission via infected semen has been documented up to seven weeks after clinical recovery. After obtention of two consecutive negative test results, MVD survivors can safely resume normal sexual practices with a minimized risk of Marburg virus transmission. In the absence of a semen testing programme, male survivors should follow safer sex practices for 12 months (WHO, 2025).

Multi-hazard Context: Not Applicable.

Monitoring: The section and the table below offer an overview of monitoring for Marburg Virus Disease. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Ministry of Health, Ministry of Agriculture, Ministry of Livestock, FAO Reference Centres, WOAH Reference Centres
How is the Hazard Observed/Monitored/Forecast?	WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country’s risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021). WHO’s Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a disaster from natural hazards. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023d). Through its global early warning system, FAO has been supporting Members with risk monitoring, assessment and forecasting for animal health threats to enhance preparedness and response to animal health threats: • The Global Animal Disease Information System, EMPRES-i+, plays a crucial role in supporting countries with early warning and early detection of animal disease outbreaks. By providing a comprehensive platform for real-time disease tracking, EMPRES-i+, enables monitoring and analysis of animal health threats effectively, collaborating closely with countries and regions on disease information sharing. This supports the dissemination of risk assessments and

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	alerts for evidence-based decision-making. • FAO develops and maintains decision support tools that provide risk maps of existing and predicted risks of animal disease emergence, as well as other threats to the agri food chain. • Additionally, FAO collaborates closely with international organizations like WHO and WOAH to verify disease information through integrated mechanisms such as the Epidemic Intelligence from Open Sources (EIOS), the Global Early Warning System (GLEWS+), and the World Animal Health Information System (WAHIS) for WOAH-listed diseases. These collaborations allow for the dissemination of early warning alerts and risk assessments to Members, to enable timely responses to potential outbreaks. FAO empres-i+ https://empres-i.apps.fao.org/diseases Rift Valley fever (RVF) Early Warning Decision Support Tool (RVF DST) WOAH WAHIS https://wahis.woah.org/#/event-management

Risk Management: Good outbreak control relies on using a range of interventions, namely case management, surveillance and contact tracing, a good laboratory service, safe and dignified burials, and social mobilization (WHO, 2025).

As an example, Rwanda reported its first MVD outbreak. As of 9 October 2024, 58 cases, including 13 deaths, were reported in the country. According to limited available information, the majority were healthcare workers. Cases were reported from eight of Rwanda's 30 districts. In response to this outbreak, the Rwandan Ministry of Health implemented measures such as restrictions on hospital visits and attendance at funerals, measures for educational settings, places of worship, and meetings, as well as travel advice. Routine temperature checks were conducted at points of entry and exit screening was implemented at Kigali airport. Vaccination of healthcare workers with an investigative vaccine was also being implemented (ECDC, 2024).

Community engagement is key to successfully controlling any outbreaks. Outbreak control relies on using a range of interventions, such as case management, surveillance and contact tracing, good laboratory service, infection prevention and control in health facilities, safe and dignified burials and social mobilization. Raising awareness of risk factors for MVD and protective measures that individuals can take is an effective way to reduce human transmission (WHO, 2025). Risk reduction messaging should focus on several factors:

- ***Reducing the risk of bat-to-human transmission*** arising from prolonged exposure to mines or caves inhabited by fruit bat colonies. People visiting or working in mines or caves inhabited by fruit bat colonies, people should wear gloves and other appropriate protective clothing (including masks). During outbreaks all animal products (blood and meat) should be thoroughly cooked before consumption.
- ***Reducing the risk of human-to-human transmission in the community*** arising from direct or close contact with infected patients, particularly with their body fluids. Close physical contact with MVD patients should be avoided. Patients suspected or confirmed for MVD should be isolated in a designated treatment centre for early care and to avoid transmission at home.
- ***Communities affected by MVD*** should make efforts to ensure that the population is well informed, both about the nature of the disease itself and about necessary outbreak containment measures.
- ***Outbreak containment measures*** include safe and dignified burial of the deceased, identifying people who may have been in contact with someone infected with MVD and monitoring their health for 21 days, separating the healthy from the sick to prevent further spread and providing care to the confirmed patient and maintaining good hygiene and a clean environment need to be observed (WHO, 2025).

Healthcare workers should always take standard precautions when caring for patients, regardless of their presumed diagnosis. These include basic hand hygiene, respiratory hygiene, use of personal protective equipment (to block splashes or other contact with infected materials), safe injection practices and safe and dignified burial practices. Healthcare workers caring for patients with suspected or confirmed MVD should apply extra infection control measures to prevent contact with the patient's blood and body fluids and contaminated surfaces or materials such as clothing and bedding. Laboratory workers are also at risk. Samples taken from humans and animals for investigation of Marburg virus infection should be handled by trained staff and processed in suitably equipped laboratories (WHO, 2025).

All survivors, their partners and families should be shown respect, dignity and compassion. WHO does not recommend isolation of male or female convalescent patients whose blood has been tested negative for Marburg virus. MVD survivors might suffer from both clinical and psychological sequelae. WHO encourages affected countries to consider the establishment of a survivor care programme to alleviate sequelae, support community reintegration and offer counselling and biological testing. Marburg virus is known to persist in immune-privileged sites in some people who have recovered. These sites include the testicles and the inside of the eye. Extrapolating from data on other filoviruses, the virus may persist in the placenta, amniotic fluid and foetus of women infected while pregnant and the breast milk of women infected while breastfeeding. Relapse-symptomatic illness in the absence of re-infection in someone who has recovered from MVD is a rare event but has been documented. The reasons for this phenomenon are not yet fully understood.

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Marburg virus transmission via infected semen has been documented up to seven weeks after clinical recovery (WHO, 2025). To mitigate the risk of potential transmission via exposure to infected semen, a semen testing programme should be implemented to:

- offer counselling to male MVD survivors and their sexual partners, as needed, to inform them of potential risks and support them in adhering to safer sex practices (including condom provision and good hand and personal hygiene); and
- offer monthly semen testing until the obtention of two consecutive negative test results.

After obtention of two consecutive negative test results, MVD survivors can safely resume normal sexual practices with a minimized risk of Marburg virus transmission. In the absence of a semen testing programme, male survivors should follow safer sex practices for 12 months (WHO, 2025).

WHO aims to prevent MVD outbreaks by maintaining surveillance for MVD disease and supporting at-risk countries to develop preparedness plans. The following document provides overall guidance for control of Ebola and Marburg disease outbreaks: When an outbreak is detected WHO responds by supporting surveillance, community engagement, case management, laboratory services, infection prevention and control, logistical support and training and assistance with safe burial practices.

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0052 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Measles (Human)

Definition

Measles is a highly contagious, serious disease caused by a virus from the paramyxovirus family. It spreads easily when an infected person breathes, coughs or sneezes. It can cause severe disease, complications, and even death (adapted from WHO 2024).

Reference

WHO, 2024. Measles. World Health Organization (WHO). https://www.who.int/news-room/fact-sheets/detail/measles Accessed 25 May 2025.

Preliminary – Corrections Pending

Annotations

Synonym

Rubeola.

Additional scientific description

Measles is a highly contagious viral disease which affects susceptible individuals of all ages and remains one of the leading causes of death among young children globally, despite the availability of safe and effective measles-containing vaccines. It is transmitted via droplets from the nose, mouth, or throat of infected persons. Initial symptoms, which usually appear 10 to 12 days after infection, include high fever, usually accompanied by one or more of the following: runny nose, conjunctivitis, cough and tiny white spots on the inside of the mouth. Several days later, a rash develops, starting on the face and upper neck and gradually spreads downwards. A patient is infectious four days before the start of the rash to four days after the appearance of the rash. Most people recover within two to three weeks (WHO, 2019).

Before the introduction of the measles vaccine in 1963 and widespread vaccination, major epidemics occurred approximately every two to three years and caused an estimated 2.6 million deaths each year (WHO, 2024).

Serious complications are more common in children under the age of 5 years, or in adults over the age of 30 years. The most serious complications include blindness, encephalitis (an infection that causes brain swelling), severe diarrhoea and related dehydration, ear infections, or severe respiratory infections such as pneumonia (WHO, 2024).

Even with the implementation of routine immunisation, measles continues to circulate globally due to suboptimal vaccination coverage and population immunity gaps. Any community with less than 95% population immunity is at risk for an outbreak. If an outbreak response is not timely and comprehensive, the virus will find its way into more pockets of vulnerable individuals and potentially spread within and beyond the affected countries (WHO, 2019).

The impact on public health will persist until the ongoing outbreaks are controlled, routine immunisation coverage is continuously high (≥95%) and immunity gaps in the population are closed. As long as measles continues to circulate anywhere in the world, no country can be assured of avoiding importation. However, countries can protect their populations through high vaccine coverage achieved primarily through routine immunisation programmes, and where necessary through supplemental immunisation activities designed to ensure that susceptible individuals are vaccinated (WHO, 2019).

Although the measles virus is related to several other viruses that infect animals, humans are the only reservoir for the measles virus. It is therefore theoretically possible that measles could be eradicated from the world (ECDC, no date).

WHO published the Measles and rubella strategic framework in 2020, establishing seven necessary strategic priorities to achieve and sustain the regional measles and rubella elimination goals (WHO, 2020a).

Metrics and numeric limits

Vaccination decreased the estimated measles deaths from 800,062 in 2000 to 107,500 in 2022 (WHO, 2024).

Even though a safe and cost-effective vaccine is available, in 2023, there were an estimated 107,500 measles deaths globally, mostly among unvaccinated or under vaccinated children under the age of 5 years (WHO, 2024).

In 2023, 74% of children received both doses of the measles vaccine, and about 83% of the world's children received one dose of measles vaccine by their first birthday (WHO, 2024). Approximately 22 million infants missed at least one dose of measles vaccine through routine immunisation in 2023 (WHO, 2024).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Any non-immune person (not vaccinated or vaccinated but did not develop immunity) can become infected. Unvaccinated young children and pregnant persons are at highest risk of severe measles complications (WHO, 2024).

Measles is still common, particularly in parts of Africa, the Middle East and Asia. The COVID-19 pandemic led to setbacks in surveillance and immunization efforts. The suspension of immunization services and declines in immunization rates and surveillance across the globe left millions of children vulnerable to preventable diseases like measles (WHO, 2024).

The risk of measles outbreaks is particularly high amongst refugees, who should be vaccinated as soon as possible (WHO, 2024).

Impacts: Complications are most common in children under 5 years and adults over 30. They are more likely in children who are malnourished, especially those without enough vitamin A or with a weak immune system from HIV or other diseases. Measles itself also weakens the immune system and can make the body “forget” how to protect itself against infections, leaving children extremely vulnerable. The virus remains active and contagious in the air or on infected surfaces for up to two hours. For this reason, it is very infectious, and one person infected by measles can infect nine out of 10 of their unvaccinated close contacts. It can be transmitted by an infected person from four days prior to the onset of the rash to four days after the rash erupts (WHO, 2024).

Multi-hazard Context: The overwhelming majority of measles deaths occur in countries with low per capita incomes or weak health infrastructures that struggle to reach all children with immunization. Damaged health infrastructure and health services in countries experiencing or recovering from a natural disaster or conflict interrupt routine immunization and overcrowding in residential camps increases the risk of infection. Children with malnutrition or other causes of a weak immune system are at highest risk of death from measles (WHO, 2024).

Monitoring: WHO-coordinated surveillance networks have been established for specific vaccine-preventable diseases (VPDs) to provide support to Ministries of Health and surveillance sites. Because some illnesses such as diarrhoea or fever/rash can be caused by several pathogens, global laboratory networks are needed to accurately confirm if the cause is a specific VPD organism, such as rotavirus or measles. In 2017, WHO and UNICEF disseminated the surveillance questionnaire together with the Joint Reporting Form to all 194 WHO Member States. The questionnaire requested information on the current status of surveillance for 28 current and potential future VPDs, attributes of surveillance conducted for each VPD, and details about current measles and rubella surveillance system(s) in each count (WHO, 2020b).

Risk Management: While there is no specific antiviral treatment for measles, community-wide vaccination is the most effective way to prevent measles. All children should be vaccinated against measles. The vaccine is safe, effective and inexpensive (WHO, 2024).

Children should receive two doses of the vaccine to ensure they are immune. The first dose is usually given at 9 months of age in countries where measles is common and 12-15 months in other countries. A second dose should be given later in childhood, usually at 15-72 months. Children or adults with measles should receive two doses of vitamin A supplements, given 24 hours apart. This restores low vitamin A levels that occur even in well-nourished children. It can help prevent eye damage and blindness. Vitamin A supplements may also reduce the number of measles deaths (WHO, 2024).

Routine measles vaccination combined with mass immunization campaigns in countries with high case rates are crucial for reducing global measles deaths. Two doses of the vaccine are recommended to ensure immunity and prevent outbreaks, as not all children develop immunity from the first dose (WHO, 2024).

The WHO urged all Member States to do the following (WHO, 2019b):

- Maintain high measles vaccination coverage (≥95%) with two doses of measles-containing-vaccine, in every district.
- Offer vaccination to individuals who do not have proof of vaccination or immunity against measles, and who are at risk of infection and transmission of the virus, such as healthcare workers, people working in tourism and transportation, and international travellers.
- Strengthen epidemiological surveillance for cases of ‘fever with rash’ for timely detection of all suspected cases of measles in public and private healthcare facilities.

Preliminary – Corrections Pending

- Ensure that collected blood samples from suspect measles cases are appropriately tested by laboratories within five days.
- All countries need to provide a rapid response to imported measles cases to prevent the establishment or re-establishment of endemic transmission.
- Recognise complications early and provide comprehensive treatment to reduce the severity of disease and avoid unnecessary deaths.
- Administer vitamin A supplementation to all children diagnosed with measles to reduce complications and mortality: two doses of 50,000 IU for a child less than 6 months of age, 100,000 IU for children between 6 and 12 months of age or 200,000 IU for children 12 to 59 months of age, immediately upon diagnosis and on the following day.
- Ensure healthcare workers are vaccinated in order to avoid infections acquired in a health-care setting.

The WHO and partners coordinate their support to Member States via their public health response by calling for the following activities: enhancing preparedness for measles outbreak response; strengthening public trust in vaccines; strengthening surveillance, risk assessment and outbreak investigations; improving clinical management of measles cases; implementing outbreak response immunisation activities; and evaluating outbreak response activities (WHO, 2019).

The WHO has established a measles outbreak Incident Management Support system to coordinate its support to affected countries (WHO, 2019).

In 2020, WHO and global stakeholders endorsed the Immunization Agenda 2021-2030. The Agenda aims to achieve the regional targets as a core indicator of impact, positioning measles as a tracer of a health system's ability to deliver essential childhood vaccines. Based on current trends of measles vaccination coverage and incidence, the WHO Strategic Advisory Group of Experts on Immunization (SAGE concluded that measles elimination is under threat, as the disease resurged in numerous countries that achieved, or were close to achieving, elimination (WHO, no date a). WHO continues to strengthen the Global Measles and Rubella Laboratory Network (GMRLN) to ensure timely diagnosis of measles and track the virus' spread to assist countries in coordinating targeted vaccination activities and reduce deaths from this vaccine-preventable disease (WHO, 2024; WHO no date b).

The Measles and rubella strategic framework 2021-2030 (M&RP) is a partnership led by the American Red Cross, United Nations Foundation, Centers for Disease Control and Prevention (CDC), Gavi, the Vaccines Alliance, the Gates Foundation, UNICEF and WHO, to achieve the IA2030 measles and rubella specific targets (WHO, 2020a). Launched in 2001, as the Measles and Rubella Initiative, the revitalized Partnership is committed to ensuring no child dies from measles or is born with congenital rubella syndrome. The Partnership helps countries plan, fund and measure efforts to permanently stop measles and rubella (WHO, 2024).

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a disaster from natural hazards. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023).

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Coordinating agency or organisation

World Health Organisation.

Preliminary – Corrections Pending

BI0222 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Meningococcal Meningitis (Human)

Definition

Meningococcal meningitis is a bacterial form of meningitis, a serious infection of the thin lining that surrounds the brain and spinal cord, that is caused by the bacterium *Neisseria meningitidis*. Meningococcal meningitis has the potential to cause large-scale epidemics and is observed worldwide (adapted from WHO, 2025).

Reference

WHO, 2025. Meningitis. World Health Organization (WHO). www.who.int/news-room/fact-sheets/detail/meningococcal-meningitis Accessed 25 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Meningitis, *Neisseria meningitis*, meningococcal cerebrospinal fever, epidemic meningitis

Additional scientific description

Meningococcal meningitis is a bacterial form of meningitis. Of the twelve types of *Neisseria meningitidis*, called serogroups, six (A, B, C, W, X, Y) can cause epidemics. The bacteria can be carried in the nasopharyngeal tract without causing symptoms and are transmitted through droplets of respiratory or throat secretions upon close and prolonged contact. It is believed that 1% to 10% of the population are asymptomatic carriers (WHO, 2025).

The average incubation period is four days but can range from two to ten days. The most common symptoms are a stiff neck, high fever, sensitivity to light, confusion, headaches and vomiting. Some cases may develop haemorrhagic rash. Meningococcal meningitis can kill in hours and if untreated, is fatal in 50% of cases. It may result in brain damage, hearing loss or disability in 10% to 20% of survivors (WHO, 2025).

Diagnosis of meningococcal meningitis relies on lumbar puncture showing a purulent spinal fluid. The bacteria can sometimes be seen in microscopic examinations of the spinal fluid. Diagnosis is confirmed by growing the bacteria from specimens

of spinal fluid or blood or by polymerase chain reaction (PCR). Identification of the serogroups and susceptibility testing to antibiotics are important to define control measures (WHO, 2025).

The African meningitis belt is an area of increased risk of invasive meningococcal disease that stretches across Africa from Senegal and The Gambia on the western coast to Ethiopia and neighbouring countries in the east. The meningitis belt is characterized by a very high burden of disease, distinct seasonal patterns, pluri-annual cycles of outbreaks and local geographic variation in incidence. Outbreaks in the meningitis belt typically begin during the dry season, rapidly building up to a peak and subsiding abruptly with the start of the rainy season. Serogroup A was responsible for causing the majority of cases in the meningitis belt during annual epidemics of meningococcal disease from early in the twentieth century until recently, leading to tens of thousands of cases and thousands of deaths (WHO, 2020).

Surveillance, from case detection to investigation and laboratory confirmation is essential to the control of meningococcal meningitis. The World Health Organization (WHO) has published recommendations on types of surveillance and case definitions for vaccine preventable diseases (WHO, 2018).

Metrics and numeric limits

In 2019, there were an estimated 236 000 deaths (95% uncertainty interval [UI] 204 000-277 000) and 2·51 million (2·11-2·99) incident cases due to meningitis globally. The burden was greatest in children younger than 5 years, with 112 000 deaths (87 400-145 000) and 1·28 million incident cases (0·947-1·71) in 2019 (GBD, 2023).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: The geographic distribution and epidemic potential differ according to the serogroup of *Neisseria meningitidis*. There are no reliable estimates of global meningococcal disease burden due to inadequate surveillance in several parts of the world. During the dry season between December to June, dust winds, cold nights and upper respiratory tract infections combine to damage the nasopharyngeal mucosa, increasing the risk of meningococcal disease (WHO, 2025).

Higher risk is seen when people are living in close proximity, for example at mass gatherings, in refugee camps, in overcrowded households or in student, military and other occupational settings. Immune deficiencies such as HIV infection or complement deficiency, immunosuppression, and active or passive smoking can also raise the risk of different types of meningitis (WHO, 2025).

Meningococcal meningitis outbreaks occur more frequently under special risk conditions, such as crowded settings where people are in close proximity, mining areas, mass gatherings, such as religious or sporting events, settings with refugees or displaced persons, closed institutions, military camps and areas with high migration, such as high-traffic markets and border areas (WHO, 2025). Immunocompromised and/or people living with HIV are at increased risk of different types of meningitis (WHO, 2025).

Meningococcus is transmitted by aerosol or direct contact with respiratory secretions of patients or healthy human carriers. As a rule, endemic disease occurs primarily in children and adolescents, with highest attack rates in infants aged 3-12 months, whereas in epidemics older children and young adults may be more involved. Nasopharyngeal carriage of meningococci is most common among adolescents and young adults, less so among young children and relatively rare in adult populations.

Impacts: Transient nasopharyngeal carriage rather than disease is the normal outcome of meningococcal colonization. However, the rapid progression of meningococcal disease frequently results in death within 1-2 days after onset. 5-15% of children and young adults carry meningococci in the nose and throat, so chemoprophylaxis is of little value for the control of most endemic and epidemic disease. Immunization is the only rational approach to the control of meningococcal disease (WHO, 2024).

Globally, the highest burden of disease is seen in a region of sub-Saharan Africa, known as the African meningitis belt, which stretches from Senegal to Ethiopia, and is at high risk of recurrent epidemics of meningococcal meningitis (WHO, 2025).

Multi-hazard Context: Not Applicable.

Monitoring: Surveillance, from case detection to investigation and laboratory confirmation, is essential to the control of meningitis (WHO, 2025). Main objectives include:

- detect and confirm outbreaks;
- monitor the incidence trends, including the distribution and evolution of serogroups and serotypes;
- estimate the disease burden;
- monitor the antibiotic resistance profile;
- monitor the circulation, distribution, and evolution of specific strains (clones); and
- estimate the impact of meningitis control strategies, particularly preventive vaccination programmes (WHO, 2025).

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021b).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a disaster from natural hazards. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023).

Risk Management: As a rule, endemic disease occurs primarily in children and adolescents, with highest attack rates in infants aged 3-12 months, whereas in epidemics older children and young adults may be more involved. Nasopharyngeal carriage of meningococci is most common among adolescents and young adults, less so among young children and relatively rare in adult populations. Transient nasopharyngeal carriage rather than disease is the normal outcome of meningococcal colonization. However, the rapid progression of meningococcal disease frequently results in death within 1-2 days after onset. 5-15% of children and young adults carry meningococci in the nose and throat, so chemoprophylaxis is of little value for the control of most endemic and epidemic disease. Immunization is the only rational approach to the control of meningococcal disease (WHO, no date).

Licensed vaccines against meningococcal disease have been available for more than 40 years, but to date no universal vaccine against meningococcal disease exists. Vaccines are serogroup specific and confer varying degrees of duration and protection.

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They are used for prevention (routine immunisation) and in response to outbreaks (prompt reactive vaccination) In the African meningitis belt, meningococcus serogroup A accounted for 80–85% of meningitis epidemics before the introduction of a meningococcal A conjugate vaccine through mass preventive campaigns (since 2010) and into routine immunization programmes (since 2016). Continuing introduction into routine immunization programmes and maintaining high coverage is critical to avoid the resurgence of epidemics (WHO, 2025).

Antibiotics for close contacts of those with meningococcal disease, when given promptly, decreases the risk of transmission. Outside the African meningitis belt, chemoprophylaxis is recommended for close contacts within the household. Within the meningitis belt, chemoprophylaxis for close contacts is recommended in non-epidemic situations. Ciprofloxacin is the antibiotic of choice, and ceftriaxone an alternative (WHO, 2025).

The global roadmap Defeating Meningitis by 2030 was developed by WHO with the support of many partners. The strategy was approved in the first ever resolution on meningitis by the World Health Assembly in 2020 and endorsed unanimously by WHO member states. The roadmap sets a comprehensive vision “Towards a world free of meningitis” and has 3 visionary goals, including elimination of bacterial meningitis epidemics, reduction of cases of vaccine-preventable bacterial meningitis by 50% and deaths by 70%; and reduction of disability and improvement of quality of life after meningitis due to any cause (WHO, 2021a; 2025).

WHO is working on the Draft Intersectoral global action plan on epilepsy and other neurological disorders 2022 in consultation with Member States to address many challenges and gaps in providing care and services for people with epilepsy and other neurological disorders that exist worldwide (WHO, 2022).

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Coordinating agency or organisation

World Health Organisation.

Preliminary - Corrections Pending

BI0223 / BIOLOGICAL / Infectious Diseases (Human and Animal)

zoonosis

Middle East Respiratory Syndrome (MERS) (Human and Animal)

Definition

Middle East respiratory syndrome (MERS) is a viral respiratory disease caused by Middle East respiratory syndrome coronavirus (MERS-CoV) with a clinical spectrum of infection ranging from no symptoms (asymptomatic) or mild respiratory symptoms to severe acute respiratory disease and death (adapted from WHO, 2022).

Reference

WHO, 2022. Middle East respiratory syndrome corona (MERS-CoV). World Health Organization (WHO). www.who.int/en/news-room/fact-sheets/detail/middle-east-respiratory-syndrome-coronavirus-(mers-cov) Accessed 26 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

MERS-CoV disease.

Additional scientific description

Middle East respiratory syndrome (MERS) is a zoonotic disease that can be transmitted between animals and people mostly in countries in the Middle East (WHO, 2022). Since the identification of MERS-CoV in 2012, 27 Member States have reported human cases of MERS to WHO under the International Health Regulations (2005): Algeria, Austria, Bahrain, China, Egypt, France, Germany, Greece, Islamic Republic of Iran, Italy, Jordan, Kuwait, Lebanon, Malaysia, the Netherlands, Oman, Philippines, Qatar, Republic of Korea, Kingdom of Saudi Arabia, Thailand, Tunisia, Türkiye, United Arab Emirates, United Kingdom, United States of America, and Yemen. Approximately 80% of human cases have been reported by Saudi Arabia. Cases identified outside the Middle East are usually individuals who appear to have been infected in the Middle East and then travelled to areas outside the region. To date, a limited number of outbreaks have occurred outside the Middle East (WHO, 2022).

A typical presentation of MERS-CoV disease in humans is fever, cough and shortness of breath. Pneumonia is a common finding. Gastrointestinal symptoms, including diarrhoea, have also been reported. Severe illness can cause respiratory failure. The mortality rate among MERS patients is approximately 36%. However, this figure may be inflated due to the potential underreporting of mild cases that are not detected by current surveillance systems, and the case fatality ratio (CFR) is calculated based only on laboratory-confirmed cases (WHO, 2024).

Diagnosis is made with clinical, radiological, or histopathological evidence of pulmonary disease, following WHO guidance (WHO, 2018). Relation to other confirmed cases and any history of residence or travel in countries where MERS-CoV is known to be circulating is also used (WHO, 2022).

No vaccine or specific treatment is currently available, however, several MERS-CoV specific vaccines and treatments are in development. Treatment is supportive and based on the patient's clinical condition (WHO, 2022).

The World Health Organization (WHO) has published guidance on case classification and surveillance standards (WHO, 2017).

Dromedary camels (Camelus dromedarius) have been confirmed by several studies to be the natural host. MERS-CoV has been reported to cause little to no disease in camels (WOAH, 2024a). Since 2012, the following countries reported serological and/or virological evidences of MERS-CoV circulation in camels (including old retrospective samples collected before 2012): Algeria, Bangladesh, Burkina Faso, Djibouti, Egypt, Ethiopia, Iran, Iraq, Israel, Jordan, Kazakhstan, Kenya, Kuwait, Mali, Mongolia, Morocco,

Nigeria, Oman, Pakistan, Qatar, Saudi Arabia (KSA), Senegal, Somalia, Spain (Canary Islands), Sudan, Tunisia, Uganda, United Arab Emirates (FAO, 2024).

Metrics and numeric limits

Since April 2012, and as of 12 May 2025, a total of 2,638 cases of MERS, including 957 deaths, have been reported by health authorities worldwide (ECDC, 2025).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Divers: Middle East respiratory syndrome (MERS) is a zoonotic disease that can be transmitted between animals and people mostly in countries in the Middle East (WHO, 2022).

Studies have shown that humans are infected through direct or indirect contact with infected dromedary camels, although the exact route of transmission remains unclear. MERS-CoV has been identified in dromedary camels in several Member States in the Middle East, Africa and South Asia. (WHO, 2022). The virus is endemic in dromedary camels in Africa and Middle East and the movement of pastoralist and nomadic people with their camels increases the risk of transmission of the virus (Gardner et al, 2019).

Impacts: The clinical spectrum of MERS-CoV infection ranges from no symptoms (asymptomatic) or mild respiratory symptoms to severe acute respiratory disease and death. A typical presentation of MERS is fever, cough and shortness of breath. Pneumonia is a common finding, but MERS patients may not always develop this condition. Gastrointestinal symptoms, including diarrhoea, have also been reported. Severe illness can cause respiratory failure that requires mechanical ventilation or support in an intensive care unit. Older people, people with weakened immune systems, and those with chronic diseases such as renal disease, cancer, chronic lung disease, hypertension, cardiovascular disease and diabetes appear to be at greater risk of developing severe disease. Approximately 35% of cases reported to WHO have died, but this may be an overestimate of the true mortality rate, as mild cases of MERS may be missed by existing surveillance systems. (WHO, 2024).

Multi-hazard Context: T MERS-CoV appears to cause more severe disease in people with underlying health conditions such as diabetes, renal failure, chronic lung disease, and immunocompromised persons. Those with underlying medical conditions are at increased vulnerability and should avoid close contact with animals, particularly dromedaries, when visiting farms, markets, or barn areas where the virus may be circulating. General hygiene measures should be followed, such as regular hand washing with soap and water or hand hygiene with alcohol-based hand rub, before and after touching animals. Contact with sick animals should be avoided. Food hygiene practices should be observed. People should avoid drinking raw camel milk or camel urine or eating meat that has not been properly cooked (WHO, 2024).

Trade barriers may be put in place, affecting the livelihoods of communities.

Monitoring: The section and the table below offer an overview of monitoring for MERS. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	WHO, Ministry of Health, FAO Reference Centres, WOAH Reference Centres
How is the Hazard Observed/Monitored/Forecast?	EuFMD FMD quarterly reports https://www.fao.org/eufmd/resources/reports/quarterlyreport/en/ FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023).

Risk Management: Appropriately processing animal products through cooking, pasteurisation, or handling, to avoid cross-contamination is also essential (WHO, 2022).

Humans acquire MERS-CoV through either direct or indirect interaction with dromedary camels, which serve as the virus's natural

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host and zoonotic reservoir. MERS-CoV has demonstrated the ability to transmit between humans. To date, instances of non-sustained human-to-human transmission have been observed primarily among close contacts and within health-care environments. Outside of health-care settings there has been limited human-to-human transmission to date (WHO, 2024). Health-care-associated outbreaks have occurred in several countries, with the largest outbreaks seen in Saudi Arabia, the United Arab Emirates, and the Republic of Korea (WHO, 2022).

Together with affected Member States and international technical partners and networks, WHO is coordinating the global health response to MERS, including: the provision of updated information on the epidemiological situation; conducting risk assessments and joint investigations with national authorities; convening scientific meetings; and developing technical guidance and training materials for health authorities and technical health agencies. WHO is also working with the Food and Agriculture Organization of the United Nations (FAO) and the World Organization for Animal Health (WOAH) and national governments to develop public health prevention strategies to limit zoonotic transmission and amplification in humans, including the development of human and dromedary camel vaccine candidates (WHO, 2022).

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0224 / BIOLOGICAL / Infectious Diseases (Human and Animal)

zoonosis

Mpox (Human)

Definition

Mpox, previously known as monkeypox, is a viral illness caused by the monkeypox virus, a species of the genus *Orthopoxvirus*. There are two distinct clades of the virus: clade I (with subclades Ia and Ib) and clade II (with subclades IIa and IIb). Mpox can be fatal in some cases (adapted from WHO, 2024).

Reference

WHO, 2024. Mpox. World Health Organization. https://www.who.int/news-room/fact-sheets/detail/mpox Accessed 26 May 2025.

Preliminary – Corrections Pending

Annotations

Synonym

Monkeypox

Additional scientific description

Mpox is caused by the monkeypox virus (MPXV). It is an enveloped double-stranded DNA virus of the *Orthopoxvirus* genus in the Poxviridae family, which includes variola, cowpox, vaccinia and other viruses. There are two distinct clades of the virus: clade I (with subclades Ia and Ib) and clade II (with subclades IIa and IIb) (WHO, 2024a).

The natural reservoir of the virus is unknown, but various small mammals such as squirrels and monkeys are susceptible. Mpox can be transmitted through close contact with someone who has mpox, with contaminated materials, or with infected animals. During pregnancy, the virus may be passed to the foetus, or to the newborn during or after birth (WHO, 2024a).

Mpox causes signs and symptoms which usually begin within a week but can start 1-21 days after exposure. Symptoms typically last 2-4 weeks but may last longer in someone with a weakened immune system. Common symptoms include rash, fever, sore throat, headache, muscle aches, back pain, low energy and swollen lymph nodes. The mpox rash often begins on the face and spreads over the body, extending to the palms of the hands and soles of the feet. It can also start on other parts of the body where contact was made, such as the genitals (WHO, 2024a).

The monkeypox virus was discovered in Denmark (1958) in monkeys kept for research. The first reported human case of mpox was a nine-month-old boy in the Democratic Republic of the Congo (1970). Following the eradication of smallpox in 1980 and the end of smallpox vaccination worldwide, mpox steadily emerged in central, east and west Africa. Since then, mpox has been reported sporadically in central and east Africa (clade I) and west Africa (clade II). In 2003, an outbreak in the United States of America was linked to imported wild animals (clade II). Since 2005, thousands of cases have been reported in the Democratic Republic of the Congo every year. In 2017, mpox re-emerged in Nigeria and continues to spread between people across the country and in travellers to other destinations. In May 2022, an outbreak of mpox appeared suddenly and rapidly spread across Europe, the Americas and then all six WHO regions. In 2022, outbreaks of mpox due to clade I occurred in refugee camps in the Republic of the Sudan (WHO, 2024a).

Since 2022, there has also been an upsurge in mpox cases and deaths in the Democratic Republic of Congo. In some areas of the country, a new offshoot of clade I, called clade Ib, has been spreading person-to-person. As of mid-2024, the clade has also been reported in other countries (WHO, 2024a). Over 120 countries have reported mpox between Jan 2022 – Aug 2024, WHO Director-General Dr Tedros Adhanom Ghebreyesus has declared mpox a public health emergency of international concern (PHEIC) twice, the first time in May 2022 and the second time in August 2024 (WHO, 2024a).

There are vaccines for mpox. Vaccination should be considered along with other public health interventions (WHO, 2024a).

WHO recommends confirmation of MPXV infection based on nucleic acid amplification testing (NAAT), using real-time or conventional polymerase chain reaction (PCR) on lesion material for detection of unique sequences of viral DNA. PCR can be used alone or in combination with sequencing for clade, (WHO, 2024b).

Rope squirrels, tree squirrels, Gambian pouched rats, dormice, non-human primates and other animal species have been identified as susceptible to monkeypox virus (WHO, no date).

Metrics and numeric limits

The World Health Organization and the US Centers for Disease Control and Prevention have published guidance on surveillance, case investigation and contact tracing, diagnostic testing, clinical management, infection prevention and control and vaccine and immunization (CDC, 2024; WHO, 2019; 2022a;.2022b; 2024b; 2024c).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Exposure to body fluids or skin lesions or eating inadequately cooked meat of infected animals is a possible risk factor (WHO, 2017).

Secondary, or human-to-human, transmission can result from close contact with infected respiratory tract secretions, skin lesions of an infected person or objects recently contaminated by patient fluids or lesion materials. Transmission occurs primarily via respiratory droplets or mucous membranes, usually requiring prolonged face-to-face contact, which puts household members of active cases at greater risk of infection. Transmission can also occur by inoculation or via the placenta as in congenital pox (WHO, 2017).

Children, pregnant people and people with weak immune systems, including people living with HIV that is not well controlled, are at higher risk for serious illness and death due to complications from mpox (WHO, 2024a).

The global outbreak has affected primarily (but not only) gay, bisexual, and other men who have sex with men and has spread person-to-person through sexual networks.

Groups that may be at high risk of mpox include:

- health and care workers at risk of exposure,
- people in the same household or close community as someone who has mpox, including children,
- people who have multiple sex partners, including men who have sex with men; and
- sex workers of any gender and their clients.

Impacts: Some people with mpox become very sick. For example, the skin can become infected with bacteria, leading to abscesses or serious skin damage. Other complications include pneumonia; corneal infection with loss of vision; pain or difficulty swallowing; vomiting and diarrhoea causing dehydration or malnutrition; and infections of the blood (sepsis), brain (encephalitis), heart (myocarditis), rectum (proctitis), genital organs (balanitis) or urinary passages (urethritis). Mpox can be fatal in some cases (WHO, 2024a).

Stigma and discrimination against any disease are never acceptable. Stigma linked to mpox can undermine public health efforts or prolong a disease outbreak, as people may be more reluctant to come forward and seek care and treatment. For mpox, stigma, discrimination and racism have been particularly directed against communities initially most affected by the disease, namely men who have sex with men, trans people and gender-diverse communities (WHO, 2024a).

Multi-hazard Context: The natural reservoir of the Mpox virus is unknown, but various small mammals such as squirrels and monkeys are susceptible. Mpox can be transmitted through close contact with someone who has mpox, with contaminated materials, or with infected animals. During pregnancy, the virus may be passed to the foetus, or to the newborn during or after birth (WHO, 2024a).

In May 2022, an outbreak of mpox appeared suddenly and rapidly spread across Europe, the Americas and then all six WHO regions. The global outbreak has affected primarily (but not only) gay, bisexual, and other men who have sex with men and has spread person-to-person through sexual networks. More information on the global outbreak is available here, including information on community responses to control the outbreak. (WHO, 2024a).

In 2022, outbreaks of mpox due to clade I occurred in refugee camps in the Republic of the Sudan.

Since 2022, there has also been an upsurge in mpox cases and deaths in the Democratic Republic of Congo. In some areas of the country, a new offshoot of clade I, called clade Ib, has been spreading person-to-person. As of mid-2024, the clade has also been reported in other countries. (WHO, 2024a).

Preliminary – Corrections Pending

Over 120 countries have reported mpox between Jan 2022 – Aug 2024, with over 100,000 laboratory-confirmed cases reported and over 220 deaths among confirmed cases (WHO, 2024a).

Monitoring: The section and the table below offer an overview of monitoring for mpox. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	WHO, Ministry of Health, Ministry of Agriculture, Ministry of Livestock, FAO Reference Centres, WOAH Reference Centres
How is the Hazard Observed/Monitored/Forecast?	WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021). WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023) Through its global early warning system, FAO has been supporting Members with risk monitoring, assessment and forecasting for animal health threats, to enhance preparedness and response to animal health threats: • The Global Animal Disease Information System, EMPRES-i+, plays a crucial role in supporting countries with early warning and early detection of animal disease outbreaks. By providing a comprehensive platform for real-time disease tracking, EMPRES-i+, enables the monitoring and analysis of animal health threats effectively, collaborating closely with countries and regions on disease information sharing. This supports the dissemination of risk assessments and alerts for evidence-based decision-making. • FAO develops and maintains decision support tools that provide risk maps of existing and predicted risks of animal disease emergence, as well as other threats to the agri-food chain. • Additionally, FAO collaborates closely with international organizations like WHO and WOAH to verify disease information through integrated mechanisms such as the Epidemic Intelligence from Open Sources (EIOS) and the Global Early Warning System (GLEWS+), and through the World Animal Health Information System (WAHIS) for WOAH-listed diseases. These collaborations allow for the dissemination of early warning alerts and risk assessments to Members, to enable timely responses to potential outbreaks. FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

Preliminary – Corrections Pending

Risk Management: Getting an mpox vaccine can help prevent infection (pre-exposure prophylaxis). It is recommended for people at high risk of getting mpox, especially during an outbreak. The vaccine can also be administered after a person has been in contact with someone who has mpox (post-exposure prophylaxis). In these cases, the vaccine should be given less than 4 days after contact with someone who has mpox. The vaccine can be given for up to 14 days if the person has not developed symptoms (WHO, 2022a).

To prevent the spread of mpox to others, people with mpox should isolate at home following guidance from their health care provider, or in hospital if needed, for the duration of the infectious period (from onset of symptoms until lesions have healed and scabs fall off). Covering lesions and wearing a well-fitting mask when in the presence of others may help prevent spread. Using condoms during sex will help reduce the risk of getting mpox but will not prevent spread from skin-to-skin or mouth-to-skin contact. If having sex, use condoms as a precaution for 12 weeks (about 3 months) after you have recovered. Taking a break from sexual activity with new partners during periods of increased transmission can reduce the risk of getting mpox. Those who have had contact with someone with mpox should monitor for signs and symptoms for 21 days (3 weeks) and take precautions such as avoiding sexual activity during this period (WHO, 2024a).

Some antivirals have received emergency use authorization in some countries and are being evaluated in clinical trials. To date, there is no proven effective antiviral treatment for mpox. It is a priority to continue the evaluation of therapeutics in robust clinical

trials and to focus on optimizing supportive care for patients. Conservative treatment of rash lesions is recommended depending on their stage, with aims to relieve discomfort, speed healing and prevent complications, such as secondary infections or exfoliation (WHO 2022b; 2024a).

Surveillance and rapid identification of new cases is critical for outbreak containment (WHO, 2017). The key objectives of surveillance and case investigation for mpox are to rapidly identify cases and clusters of infections as well as the sources of infection as soon as possible in order to: provide optimal clinical care; isolate cases to prevent further transmission; identify, manage and follow-up contacts to recognize early signs of infection; identify risk groups for infection and for severe disease; protect frontline health workers; and tailor effective control and prevention measures (WHO, 2024c).

Infection in people can be reduced by raising awareness of the risk factors and educating people about measures they can take to reduce exposure to the virus. Control measures include isolation of affected persons, good respiratory and hand hygiene, and other personal protective measures. Those at highest risk, such as health workers or laboratory personnel, can be protected through vaccination. A vaccine against mpox was licensed in 2019 (WHO, 2019; 2020).

Health workers caring for patients with suspected or confirmed monkeypox virus infection, or handling specimens from them, should implement standard and droplet infection control precautions (WHO, 2024a).

WHO, Member States and partners work together to prevent and respond to outbreaks of mpox. This includes coordinating research on vaccines and treatments, strengthening country health systems, and working to facilitate equitable access to vaccines, therapeutics, diagnostics and other tools (WHO, 2024a).

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0225 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Paratyphoid fever (Human)

Definition

Paratyphoid fever results from systemic infection with Salmonella enterica serotype Paratyphi. It is characterised by febrile illness and, in severe cases, gastrointestinal bleeding, altered mental status, intestinal perforation, and death (IHME 2021).

Reference

Institute for Health Metrics and Evaluation (IHME). 2021 Global Burden of Disease Cause and Risk Summary: Paratyphoid fever. Seattle, USA: IHME, University of Washington, 2021. https://www.healthdata.org/research-analysis/diseases-injuries-risks/factsheets/2021-paratyphoid-fever-level-4-disease Accessed 26 May 2025.

Preliminary - Corrections Pending

Annotations

Synonym

Enteric fever

Additional scientific description

Paratyphoid fever (together with typhoid fever, collectively known as enteric fever) is caused by *Salmonella enterica* serovars Paratyphi (S. Paratyphi) A, B and C. S (WHO, 2022)

Paratyphi A is the most common serovar while Paratyphi C is uncommon. S. Paratyphi A, like *S. Typhi*, has adapted to human hosts; it causes similar clinical syndromes to typhoid, including fevers, chills, and abdominal pain, and can be a life-threatening illness in severe cases (WHO, 2022).

Incidence rates of paratyphoid fever vary widely according to geography; it is most prevalent in South and South East Asia but is not as common in Africa. Incidence is highest among children, peaking in the 5-9-year age group. Age-specific incidence may vary by country, and children with paratyphoid are generally older than those with typhoid (WHO, 2022).

S. Paratyphi infection is primarily treated with fluoroquinolones, third-generation cephalosporins, and azithromycin. Antimicrobial resistance (AMR) remains a major threat, including the potential for extreme drug resistance and azithromycin resistance. Carbapenems are reserved for suspected infection with extensively drug-resistant strains (WHO, 2022).

Humans are the only source of these bacteria; no animal or environmental reservoirs have been identified (CDC, 2024)). The onset of illness is insidious, with gradually increasing fatigue and a fever that increases daily from low-grade to high (CDC, 2024). Headache, malaise, and anorexia are nearly universal, and abdominal pain, diarrhoea, or constipation are common (CDC 2024). Paratyphoid fever appears to have a lower case-fatality ratio than typhoid fever; however, severe cases do occur (CDC, 2024).

Blood culture is the mainstay of diagnosis in typhoid and paratyphoid fever. Bone marrow and stool cultures can also be used (Gupta et al., 2008; CDC, 2024).

Metrics and numeric limits

The Global Burden of Disease (GBD) study 2019 estimated 3.8 million cases of paratyphoid fever (due predominantly to paratyphoid A) and 23,300 deaths globally, and an age-standardized incidence of 51.3/100,000.

2·17 million (95% UI 1·56-2·96) cases of paratyphoid fever occurred in 2021, resulting in 14,300 deaths (6,000-28,900) and 1·01 million (0·457-2·00) DALYs (IHME, 2021)

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and control measures of the hazard

Hazard Drivers: Paratyphoid fever is acquired through consumption of water or food contaminated by faeces of an acutely infected or convalescent person, or a person with chronic, asymptomatic carriage (CDC, 2024).

Impacts: Paratyphoid fever is estimated to be responsible for approximately one-fifth of all enteric fever cases, but its overall relative burden compared to typhoid fever is highly variable depending on the geographic context and is reportedly increasing. There are observations that the increase may be associated with vaccination against typhoid, thus it is important to monitor the burden of paratyphoid fever, especially with the implementation of typhoid conjugate vaccines (Sundeep et al., 2008; WHO, 2022).

Multi-hazard Context: Risk for infection is high in low- and middle-income countries with endemic disease and poor access to safe food and water, and poor sanitation. Sexual contact, particularly among men who have sex with men, has been documented as a rare route of transmission (CDC, 2024).

Monitoring: WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date).

Risk Management: Antibiotic therapy shortens the clinical course of enteric fever and reduces the risk of death. Treatment decisions are complicated by high rates of resistance to many antimicrobial agents, and antimicrobial treatment should be guided by susceptibility testing. A careful travel history can inform empiric treatment choices while awaiting culture results (CDC 2024). Relapse, reinfection, and chronic carriage also can occur. Relapse occurs in ≤10% of patients 1-3 weeks after clinical recovery, requiring further antibiotic treatment. An estimated 1%-4% of treated patients become asymptomatic chronic carriers (defined as people who excrete the organism in stool for ≥12 months); a prolonged antibiotic course is usually required to eradicate the organism (CDC, 2024). Safe food and water precautions and frequent handwashing (especially before meals) are important preventative measures. available for paratyphoid fever; thus, food and water precautions are the only prevention methods (CDC, 2024).

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Preliminary – Corrections Pending

Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0226 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Typhoid Fever (Human)

Definition

Typhoid fever is a life-threatening infection caused by the bacterium *Salmonella typhi*. It is usually spread through contaminated food or water. As of 2019 estimates, there are 9 million cases of typhoid fever annually, resulting in about 110 000 deaths per year. (WHO, 2023).

Reference

WHO, 2023. Typhoid. World Health Organization (WHO). https://www.who.int/news-room/fact-sheets/detail/typhoid Accessed 14 February 2025.

Preliminary – Corrections Pending

Annotations

Synonym

Enteric Fever. *Salmonella typhi* Infection. Typhoid Fever.

Additional scientific description

Typhoid fever is a life-threatening infection caused by the bacterium *Salmonella typhi*. Once *Salmonella typhi* bacteria have been ingested, they multiply and spread into the bloodstream (WHO, 2023).

Urbanization and climate change have the potential to increase the global burden of typhoid. In addition, increasing resistance to antibiotic treatment is making it easier for typhoid to spread in communities that lack access to safe drinking water or adequate sanitation (WHO 2023).

Improved living conditions and the introduction of antibiotics resulted in a drastic reduction in typhoid fever morbidity and mortality in industrialized countries. However, the disease continues to be a public health problem in many developing areas of the WHO African, Eastern Mediterranean, South-East Asia and Western Pacific Regions (WHO, 2023).

Salmonella typhi only affects humans. It is usually spread through contaminated food or water. Once *Salmonella Typhi* bacteria are ingested, they multiply and spread into the bloodstream, invading the intestines, triggering an inflammatory response and causing systemic spread through the bloodstream. This process involves several mechanisms, including the bacteria's ability to survive the acidic environment of the stomach and invade the intestinal lining, leading to tissue damage and systemic infection (Khan & Shamim, 2022; WHO, 2023).

Persons with typhoid fever carry the bacteria in their bloodstream and intestinal tract. Symptoms include prolonged high fever, fatigue, headache, nausea, abdominal pain, and constipation or diarrhoea. Some patients may have a rash. Severe cases may lead to serious complications or even death. Typhoid fever can be confirmed through blood testing. Typhoid fever can be treated with antibiotics although increasing resistance to different types of antibiotics is making treatment more complicated (WHO, 2023). The emergence of multidrug-resistant (MDR) and extensively drug-resistant (XDR) strains in many countries of the world has raised great concern over the rise of antibiotic resistance in pathogens such as *S. typhi* (Khan & Shamim, 2022)

The World Health Organization (WHO) has published guidance on case classification and surveillance standards (WHO, 2018b).

Metrics and numeric limits

As of 2019, an estimated 9 million people get sick from typhoid and 110 000 people die from it every year (WHO, 2023).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Typhoid fever is common in places with poor sanitation and a lack of safe drinking water (WHO, 2023). Typhoid risk is

higher in populations that lack access to safe water and adequate sanitation, and children are at the highest risk (WHO, 2023).

Impacts: As of 2019, an estimated 9 million people get sick from typhoid and 110 000 people die from it every year (WHO 2023). Symptoms include prolonged fever, fatigue, headache, nausea, abdominal pain, and constipation or diarrhoea. Some patients may have a rash. Severe cases may lead to serious complications or even death. Typhoid fever can be treated with antibiotics although increasing resistance to different types of antibiotics is making treatment more complicated (WHO, 2023).

Multi-hazard Context: All travellers to endemic areas are at potential risk of typhoid fever, although the risk is generally low in tourist and business centres where standards of accommodation, sanitation and food hygiene are high (WHO, 2023).

Monitoring: WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country's risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date).

Risk Management: Access to safe water and adequate sanitation, hygiene among food handlers and typhoid vaccination are all effective in preventing typhoid fever (WHO, 2023).

Typhoid conjugate vaccine, consisting of the purified Vi antigen linked to a carrier protein, is given as a single injectable dose in children from 6 months of age and in adults up to 45 years or 65 years (depending on the vaccine). Two additional vaccines have been used for many years in older children and adults at risk of typhoid, including travellers. These vaccines do not provide long-lasting immunity (requiring repeat or booster doses) and are not approved for children younger than 2 years old:

- an injectable vaccine based on the purified antigen for people aged 2 years and above; and
- a live attenuated oral vaccine in capsule formulation for people aged over 6 years (WHO, 2023).

Two typhoid conjugate vaccines have been prequalified by WHO since December 2017 and are being introduced into childhood immunization programmes in typhoid-endemic countries.

All travellers to endemic areas are at potential risk of typhoid fever, although the risk is generally low in tourist and business centres where standards of accommodation, sanitation and food hygiene are high. Typhoid fever vaccination should be offered to travellers to destinations where the risk of typhoid fever is high (WHO, 2023).

The following recommendations will help ensure safety while travelling: ensure food is properly cooked and still hot when served; avoid raw milk and products made from raw milk – drink only pasteurized or boiled milk; avoid ice unless it is made from safe water; when the safety of drinking water is questionable, boil it or if this is not possible, disinfect it with a reliable, slow-release disinfectant agent (usually available at pharmacies); wash hands thoroughly and frequently using soap, especially after contact with pets or farm animals, or after having been to the toilet; and wash fruit and vegetables carefully, particularly if they are eaten raw. If possible, vegetables and fruits should be peeled (WHO, 2023).

WHO response for typhoid: in October 2017, the Strategic Advisory Group of Experts on Immunization (SAGE), which advises the WHO, issued a recommendation for the typhoid conjugate vaccine to be added to routine childhood immunization programmes in typhoid-endemic countries SAGE also called for the introduction of typhoid conjugate vaccines to be prioritised for countries with the highest burden of typhoid disease or high levels of antibiotic resistance to *Salmonella typhi*. (WHO, 2023).

Starting in 2019, Gavi, the Vaccine Alliance has provided funding to support typhoid conjugate vaccine use in eligible countries. As of March 2023, WHO has prequalified two conjugate vaccines for the prevention of typhoid. Typhoid conjugate vaccine has longer-lasting immunity than the older typhoid vaccines and can be given as a single dose to children from the age of 6 months.

In addition to decreasing the disease burden in endemic countries and saving lives, widespread use of the typhoid conjugate vaccine in affected countries is expected to reduce the need for antibiotics for typhoid treatment and slow the increase in antibiotic resistance in *Salmonella typhi* (WHO, 2023).

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Preliminary – Corrections Pending

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0227 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Pertussis (Human)

Definition

Pertussis is a highly contagious disease, which can be fatal, of the respiratory tract caused by the bacterium *Bordetella pertussis* (WHO, no date a).

Reference

WHO, no date a. Pertussis. World Health Organization (WHO). https://www.who.int/health-topics/pertussis#tab=tab_1. Accessed 27 May 2025.

Preliminary – Corrections Pending

Annotations

Synonym

Whooping cough.

Additional scientific description

Pertussis, also known as whooping cough, is a highly contagious respiratory infection caused by the bacterium *Bordetella pertussis*. In 2018, there were more than 151,000 cases of pertussis globally (CDC, 2024).

The first symptoms generally appear 7 to 10 days after infection. They include a mild fever, runny nose and cough, which in typical cases gradually develops into a hacking cough followed by whooping (hence the common name of 'whooping cough'). Pneumonia is a relatively common complication, and seizures and brain disease occur rarely. People with pertussis are most contagious up to about 3 weeks after the cough begins, and many children who contract the infection have coughing spells that last 4 to 8 weeks. Antibiotics are used to treat the infection (WHO, no date a).

Pertussis is diagnosed clinically by its symptoms and through laboratory confirmation. It should be suspected in anyone with a cough that does not improve within 14 days, a paroxysmal cough of any duration, or any respiratory symptoms after contact with a laboratory-confirmed case of pertussis (WHO, 2024). Of note, the symptoms in infants, in which the highest mortality is seen, may differ strongly from those in older children and adults in that the typical cough may not be present at all.

The World Health Organization (WHO) has published guidance on case classification and surveillance standards (WHO, 2018).

Metrics and numeric limits

Globally, it is estimated that there were 24.1 million pertussis cases and 160,700 deaths from pertussis in children under the age of 5 years in 2014, with periodic epidemics occurring every two to five years (WHO, 2018).

During 2023, about 84% of infants worldwide (108 million) received 3 doses of diphtheria-tetanus-pertussis (DTP3) vaccine,

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Pertussis spreads easily from person to person mainly through droplets produced by coughing or sneezing. The disease is most dangerous in infants and is a significant cause of disease and death in this age group (WHO, 2018). Immunisation, the use of vaccines to produce immunity to specific diseases, is a global health and development success story, saving millions of lives every year. Vaccination is a highly effective method of preventing certain infectious diseases. Vaccines reduce the risks of getting a disease by working with each individual's natural defences to build protection (WHO, no date b).

The most common sociodemographic determinants associated with the reduction of vaccination uptake were economic status, age, education, and household composition (Eiden et al., 2022).

Impacts: Globally, it is estimated that there were 24.1 million pertussis cases and 160,700 deaths from pertussis in children under the age of 5 years in 2014, with periodic epidemics occurring every two to five years (WHO, 2018).

Multi-hazard Context: Pertussis is easily transmitted from person to person, mainly through droplets. In 2022, there were more than 62,500 cases of pertussis globally and nearly 39,000 cases were reported in the Western Pacific Region. Pertussis can be prevented by immunisation. The Western Pacific Region had 93% coverage with three doses of diphtheria-tetanus-pertussis vaccine in 2022 (WHO, no date).

Monitoring: The objectives of pertussis surveillance are to monitor disease burden and the impact of the pertussis vaccination programme, with a special focus on understanding the morbidity and mortality in children under 5 years of age, to generate data to inform vaccine schedule and delivery strategy decisions to optimize the impact of vaccination and to detect and guide public health response to outbreaks of pertussis (WHO, 2018).

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a disaster from natural hazards. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023).

Risk Management: The best way to prevent pertussis is through immunisation. The three-dose primary series diphtheria-tetanus-pertussis (DTP3) (-containing) vaccines decrease the risk of severe pertussis in infancy. During 2023, about 84% of infants worldwide (108 million) received 3 doses of diphtheria-tetanus-pertussis (DTP3) vaccine, protecting them against infectious diseases that can cause serious illness and disability or be fatal. However, these global figures hide significant disparity among countries of different income strata, with low-income countries lagging behind (WHO, 2020; 2024)

The WHO recommends the first dose be administered as early as 6 weeks of age; with subsequent doses given 4 to 8 weeks apart (age 10-14 weeks and 14-18 weeks). A booster dose is recommended, preferably during the second year of life. Based on local epidemiology, further booster doses may be warranted later in life (WHO, no date a).

Vaccination of pregnant women is effective in preventing disease in infants too young to be vaccinated. National programmes may consider vaccination of pregnant women with pertussis-containing vaccine as a strategy additional to routine primary infant pertussis vaccination in countries or settings with high or increasing infant morbidity/mortality from pertussis (WHO, no date a).

Preliminary – Corrections Pending

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Coordinating agency or organisation

World Health Organisation.

Preliminary – Corrections Pending

BI0228 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Plague (Human)

Definition

Plague is caused by the bacteria *Yersinia pestis*, and can be a very severe disease in people, with a case-fatality ratio of 30% to 60% for the bubonic type and is always fatal for the pneumonic kind when left untreated (WHO, 2022).

Reference

WHO 2022. Plague https://www.who.int/news-room/fact-sheets/detail/plague. World Health Organization (WHO) Accessed 25 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Black Death.

Additional scientific description

Plague is an infectious disease caused by the bacteria *Yersinia pestis*, a zoonotic bacteria, usually found in small mammals and their fleas (WHO, 2022). It is transmitted between animals through fleas. Humans can be infected through:

- the bite of infected vector fleas,
- unprotected contact with infectious bodily fluids or contaminated materials,
- the inhalation of respiratory droplets/small particles from a patient with pneumonic plague (WHO, 2022).

Plague is a very severe disease in people, particularly in its septicaemic (systemic infection caused by circulating bacteria in the bloodstream); pneumonic forms, with a case-fatality ratio of 30% to 100% if left untreated, and a case-fatality ratio of 30% to 60% for the bubonic type. The pneumonic form is invariably fatal unless treated early. It is especially contagious and can trigger severe epidemics through person-to-person contact via droplets in the air (WHO, 2022).

Historically, plague was responsible for widespread pandemics with high mortality (Jedwab et al., 2021). It was known as the "Black Death" during the fourteenth century, causing more than 50 million deaths in Europe. Nowadays, plague is easily treated with antibiotics and the use of standard precautions to prevent acquiring infection. (WHO, 2022)

Plague epidemics have occurred in Africa, Asia, and South America; but since the 1990s, most human cases have occurred in Africa. The three most endemic countries are the Democratic Republic of Congo, Madagascar, and Peru. In Madagascar, cases of bubonic plague are reported nearly every year, during the epidemic season (between September and April) (WHO, 2021; 2022).

Metrics and numeric limits

Plague has killed millions of people during the past 25 centuries (Jedwab et al., 2021). Plague reappeared in several countries during the 1990s. Consequently, plague was categorized as a re-emerging disease. Human plague outbreaks continue to be reported, including an outbreak of pneumonic plague in Madagascar in 2017 (WHO, 2017; 2021a).

Plague can be a very severe disease in people, with a case-fatality ratio of 30% to 60% for the bubonic type and is always fatal for the pneumonic kind when left untreated (WHO, 2022).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Plague is transmitted between animals and humans by the bite of infected fleas, direct contact with infected tissues, and inhalation of infected respiratory droplets.

Humans can be infected through the bite of infected vector fleas, unprotected contact with infectious bodily fluids or contaminated materials, and the inhalation of respiratory droplets/small particles from a patient with pneumonic plague (WHO, 2022).

Impacts: People infected with plague usually develop acute febrile disease with other non-specific systemic symptoms after an incubation period of one to seven days, such as sudden onset of fever, chills, head and body aches, and weakness, vomiting and nausea (WHO, 2022).

There are two main forms of plague infection, depending on the route of infection: bubonic and pneumonic.

- Bubonic plague is the most common form of plague and is caused by the bite of an infected flea. Plague bacillus, Y. pestis, enters at the bite and travels through the lymphatic system to the nearest lymph node where it replicates itself. The lymph node then becomes inflamed, tense and painful, and is called a 'bubo'. At advanced stages of the infection the inflamed lymph nodes can turn into open sores filled with pus. Human-to-human transmission of bubonic plague is rare. Bubonic plague can advance and spread to the lungs, which is the more severe type of plague called pneumonic plague.
- Pneumonic plague, or lung-based plague, is the most virulent form of plague. Incubation can be as short as 24 hours. Any person with pneumonic plague may transmit the disease via droplets to other humans. Untreated pneumonic plague, if not diagnosed and treated early, can be fatal. However, recovery rates are high if detected and treated in time (within 24 hours of onset of symptoms) (WHO, 2022).

Multi-hazard Context: Over the past several hundred years, there have been three pandemics with high mortality rates (Jedwab, et al, 2021). It has been absent from Europe for more than 50 years but continues to affect the Americas, Africa and Asia. Plague is infamous for killing millions of people in Europe during the Middle Ages. People at the highest risk are those in contact with wild rodents and fleas in plague-affected areas, and travellers in high-risk areas. Plague is mainly found in rodents and transmission between rodents and humans is usually via fleas. Although human-to-human transmission is rare in the case of bubonic plague, in cases of pneumonic plague it occurs after inhalation of infectious droplets from infected persons. The main control measures are to reduce contact with wild rodents and their fleas and to establish surveillance and control programmes in risk areas (ECDC, no date).

Managing exclusionary policies where local communities are purposely or unintendedly excluded from decision and action processes contributes to inefficiency in the disease control policies adopted by authorities, especially if it causes distrust in the government, or if it spurs conflict between groups (Jedwab et al., 2021).

Monitoring: WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date)

In order to effectively and efficiently manage plague outbreaks it is crucial to have a robust surveillance system and an informed and vigilant health-care workforce (and community) to quickly diagnose and manage patients with infection, identify risk factors, conduct ongoing surveillance, control vectors and hosts, confirm diagnosis with laboratory tests, and to communicate findings with appropriate authorities (WHO, 2022).

A robust surveillance system is the key to the early warning of plague occurrences or outbreaks. This is related to a favourable outcome due to early case detection and treatment, in addition to leading to a more accurate quantification of the disease burden and geographical distribution. The plague surveillance should ideally include a combination of human, animal and climate surveillance. The surveillance system should be adapted based upon the scenario, season and early warning signs. For example, a community-based surveillance system has been used in Madagascar to strengthen early warning systems for plague (Ratsitorahina, 2000).

Risk Management: Antibiotic treatment is effective against plague bacteria, so early diagnosis and early treatment can save lives (WHO, 2022). WHO does not recommend vaccination, except for high-risk groups (such as laboratory personnel who are constantly exposed to the risk of contamination, and health-care workers) (WHO, 2022).

Preliminary – Corrections Pending

For managing plague outbreaks, WHO recommends the following:

- Find and stop the source of infection. Identify the most likely source of infection in the area where the human case(s) was exposed, typically looking for clustered areas with large numbers of small animal deaths. Institute appropriate infection, prevention and control procedures. Institute vector control, then rodent control. Killing rodents before vectors will cause the fleas to jump to new hosts, this is to be avoided.
- Protect health workers. Inform and train them on infection prevention and control. Workers in direct contact with pneumonic plague patients must wear standard precautions and receive a chemoprophylaxis with antibiotics for the duration of seven days or at least as long as they are exposed to infected patients.
- Ensure correct treatment: Verify that patients are being given appropriate antibiotic treatment and that local supplies of antibiotics are adequate.
- Isolate patients with pneumonic plague. Patients should be isolated so as not to infect others via air droplets. Providing masks for pneumonic patients can reduce spread.
- Surveillance: identify and monitor close contacts of pneumonic plague patients and give them a seven-day chemoprophylaxis. Chemoprophylaxis should also be given to household members of bubonic plague patients.
- Obtain specimens which should be carefully collected using appropriate infection, prevention and control procedures and sent to labs for testing.
- Disinfection. Routine handwashing is recommended with soap and water or use of alcohol hand rub. Larger areas can be disinfected using 10% of diluted household bleach (made fresh daily).
- Ensure safe burial practices. Spraying of the face/chest area of suspected pneumonic plague deaths should be discouraged. The area should be covered with a disinfectant-soaked cloth or absorbent material (WHO, 2022).

Preventive measures include informing people when zoonotic plague is present in their environment and advising them to take precautions against flea bites and not to handle animal carcasses. Generally, people should be advised to avoid direct contact with infected body fluids and tissues. When handling potentially infected patients and collecting specimens, standard precautions should apply (WHO, 2022).

Surveillance and control require investigating animal and flea species implicated in the plague cycle in the region and developing environmental management programmes to understand the natural zoonosis of the disease cycle and to limit spread. Active long-term surveillance of animal foci, coupled with a rapid response during animal outbreaks has successfully reduced numbers of human plague outbreaks (WHO, 2022).

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0229 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Polio (Human)

Definition

Polio (human) is a highly infectious viral disease, which mainly affects young children, where 1 in 200 leads to irreversible paralysis and among those paralysed, 5-10% die when their breathing muscles become immobilized (WHO, 2025).

Reference

WHO, 20254. Poliomyelitis. World Health Organization (WHO). https://www.who.int/news-room/fact-sheets/detail/poliomyelitis Accessed 25 May 2025

Preliminary – Corrections Pending

Annotations

Synonyms

Poliomyelitis.

Additional scientific description

Poliomyelitis (polio) is a highly infectious viral disease that largely affects children under 5 years of age. The virus is transmitted by person-to-person spread mainly through the faecal-oral route or, less frequently, by a common vehicle (e.g., contaminated water or food) and multiplies in the intestine, from where it can invade the nervous system and cause paralysis (WHO, 2025).

Polio virus infection is mostly asymptomatic. If there are symptoms these can include fever, malaise, sore throat, anorexia, myalgia, headache, and in less than 1% of infected children illness can progress to paralytic disease. Typically, the paralysis is acute onset and flaccid in nature and asymmetrically involving limbs. One in 200 infections leads to irreversible paralysis. Among those paralysed, 5% to 10% may die due to respiratory paralysis. If the child recovers, paralysis is often permanent (WHO, 2025).

Polio is diagnosed clinically through symptoms and laboratory methods (WHO, 2019). Diagnostic testing can detect poliovirus in specimens from the throat, faeces (stool), and occasionally cerebrospinal fluid (CSF). Testing works by isolating the virus in cell culture or by detecting the virus by polymerase chain reaction (PCR) (CDC, 2024).

Polio is targeted for global eradication and since 2017, only two countries (Afghanistan and Pakistan) have detected wild polio transmission. However, in recent years there has been a resurgence of vaccine-derived poliovirus (VDPV). This emerges in areas where poor vaccination coverage allows the attenuated vaccine virus to circulate and revert to a pathogenic form due to genetic mutation (GPEI, 2016; 2019).

In 1994, the WHO Region of the Americas was certified polio-free, followed by the WHO Western Pacific Region in 2000 and the WHO European Region in June 2002. On 27 March 2014, the WHO South-East Asia Region was certified polio-free, meaning that transmission of wild poliovirus has been interrupted in this bloc of 11 countries stretching from Indonesia to India. In 2020, Africa became the fifth region to be certified wild poliovirus-free (WHO, 2025).

Metrics and numeric limits

Cases due to wild poliovirus have decreased by over 99% since 1988, from an estimated 350,000 cases then, to 33 reported cases in 2018 (WHO, 2024).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Polio infection is more common in socioeconomically disadvantaged areas, especially in those where conditions are

crowded and in tropical areas where hygiene is poor (WHO, 2025). Polio mainly affects children under 5 years of age. However, anyone of any age who is unvaccinated can contract the disease.

Conflict and insecurity coupled with fragile health systems are risk factors for ongoing polio transmission particularly when these factors result in children being missed by vaccination programmes due to inaccessibility (WHO, no date).

Impacts: Cases due to wild poliovirus have decreased by over 99% since 1988, from an estimated 350,000 cases then, to 33 reported cases in 2018 (WHO, 2025).

Multi-hazard Context: Polio remains a hazard in some countries driven by natural hazards, humanitarian emergencies, droughts, earthquakes and outbreaks of other infectious diseases (WHO, 2024).

Monitoring: To date, poliovirus surveillance permitting the reliable and timely detection of all types of poliovirus (WPV, VDPV, Sabin-like viruses) is mainly conducted using Acute Flaccid Paralysis (AFP) and environmental surveillance. AFP surveillance is a case-based syndromic surveillance system used globally to identify all cases of AFP in children under 15 years, and to confirm the presence or absence of poliovirus by testing AFP case stool specimens in WHO-accredited laboratories. AFP surveillance is complemented by environmental surveillance which systematically tests sewage samples for poliovirus in specific settings (WHO, 2023).

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a disaster from natural hazards. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023d).

Risk Management: There is no cure for polio, it can only be prevented. The olio vaccine, given multiple times, can protect a child for life. There are two vaccines available: oral polio vaccine and inactivated polio vaccine. Both are effective and safe, and both are used in different combinations worldwide, depending on local epidemiological and programmatic circumstances, to ensure the best possible protection for populations can be provided (WHO, 2025).

Vaccine-derived polio viruses (VDPVs) are classified into three categories: cVDPVs (circulating), when there is evidence of transmission (more than one case), iVPVD, when the infections are confirmed in immunocompromised individuals, and aVDPV (ambiguous) that can represent the initial isolates from cVDPV outbreaks, samples isolated from individuals without documented immunodeficiencies or that are environmental samples, with no evidence of community circulation (Bricks et al., 2024).

In 1988, the World Health Assembly adopted a resolution for the worldwide eradication of polio, marking the launch of the Global Polio Eradication Initiative (GPEI), spearheaded by national governments, WHO, Rotary International, the US Centers for Disease Control and Prevention (CDC) and UNICEF, and later joined by the Bill & Melinda Gates Foundation and Gavi, the Vaccine Alliance. The Polio Eradication Strategy lays out the roadmap to securing a lasting and sustained world, free of all polioviruses, and transition and polio post-certification efforts are ongoing to ensure that the infrastructure built up to eradicate polio will continue to benefit broader public health efforts, long after the disease is gone (WHO, 2021b). Economic modelling has found that the eradication of polio would save at least US$ 40-50 billion, mostly in low-income countries. Most importantly, success will mean that no child will ever again suffer the terrible effects of lifelong polio-paralysis (WHO, 2025).

The Global Polio Eradication Initiative (GPEI), launched in 1988, has successfully reduced wild poliovirus (WPV) cases by over 99.9%, with WPV type 2 and WPV3 declared eradicated in 2015 and 2019, Since the GPEI was launched, the number of cases has fallen by over 99% (GPEI, 2019; 2023).

The global effort to eradicate polio has been declared a Public Health Initiative of International Concern, under the International Health Regulations, and temporary recommendations by an Emergency Committee under the International Health Regulations have been issued to countries affected by poliovirus transmission or are at high risk of re-emergence of the disease. The polio effort continues to support broader public health efforts, including helping respond to natural disasters, humanitarian emergencies, droughts, earthquakes, outbreaks of other infectious diseases and supporting disease surveillance for broader public health initiatives (WHO, 2025).

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Preliminary – Corrections Pending

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Coordinating agency or organisation

World Health Organisation.

Preliminary – Corrections Pending

BI0230 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Prion Diseases

Definition

Prion diseases are a family of rare progressive neurodegenerative disorders that affect both humans and animals (Adapted from CDC, 2024, WHO, no date).

Reference

CDC, 2024. Prion Diseases. Centres for Disease Control and Prevention (CDC). https://www.cdc.gov/prions/about/index.html Accessed 27 May 2025.

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Annotations

Synonyms

Transmissible Spongiform Encephalopathies, PrP, PrPc

Additional scientific description

These diseases affect the nervous system of mammals and, although the exact mechanism for transmission is as yet unknown, it is thought to be due to a putative infectious protein or protein-like substance called a prion, a ubiquitously expressed protein termed PrP or PrPc which undergoes conversion to an abnormal prion protein termed PrPsc (WHO, no date)

These diseases occur when proteins normally in the body misfold and cause illness. The misfolding leads to brain damage and other symptoms. Symptoms may take years to develop. But once they do, the disease rapidly progresses and leads to death. One of the reasons people may get sick with prion diseases is through eating or handling meat contaminated with prions. People may also become infected if they get prions in their bodies. This may occur through organ transplant or being exposed to contaminated equipment during surgery (CDC, 2024).

The term Transmissible Spongiform Encephalopathies (TSE) includes:

- Creutzfeldt-Jakob disease (CJD) in humans
- scrapie in sheep and goats
- chronic wasting disease in deer
- bovine spongiform encephalopathies (BSE) in cattle (WHO, no date)

Human

Many different prion diseases affect people, but some are more common than others. The most common prion disease in people is Creutzfeldt-Jakob disease (CJD). CJD is a prion disease that causes a person's brain to break down or stop working normally. Once symptoms start, the disease progresses quickly. It is always fatal, usually within a year. CJD is sometimes called "classic CJD" to avoid confusion with variant CJD. Most cases of classic CJD are in older people. They appear sporadically. This means there is no known reason that the cases begin.

A smaller number of cases occur in people who inherited genetic changes that make them prone to CJD. Occasionally, there have also been illnesses in people who were exposed to surgical equipment or other products contaminated with prions (CDC, 2024).

Another prion disease, variant Creutzfeldt-Jakob disease (vCJD), has a similar name but is a different, much rarer, disease (CDC, 2024). vCJD is a rare and fatal human neurodegenerative condition first described in March 1996. As with CJD, vCJD is classified as a TSE because of characteristic spongy degeneration of the brain and its ability to be transmitted. The development of vCJD is strongly linked with exposure, probably through the consumption of meat and meat products, to the agent causing BSE which was first reported in the UK in 1986. In contrast to the traditional forms of CJD (sporadic, familial, and iatrogenic), vCJD has affected younger patients, average age of 29 years, compared to >65 years for the other forms. vCJD has a relatively longer duration of illness, median of 14 months, compared to 4.5 months for CJD (WHO, no date).

Preliminary – Corrections Pending

Creutzfeldt-Jakob disease (vCJD) is tied to eating beef from a cow that had a prion disease called Bovine Spongiform Encephalopathy (BSE). It was discovered in 1996 in the United Kingdom. The disease affected much younger people than CJD. vCJD often infected people in their 20s or younger. It caused mental symptoms and behaviours, as well as pain when touching things (dysesthesias), that CJD does not (CDC, 2024).

Other prion diseases include kuru, variably protease-sensitive prionopathy, sporadic fatal insomnia, and inherited forms caused by genetic mutations (CDC, 2024). It is a non-inflammatory neurodegenerative disease and is a form of transmissible spongiform encephalopathy transmitted through the act of cannibalism (Asher, 2018). The symptoms of kuru progress rapidly with cerebellar and extrapyramidal signs and symptoms, with death occurring within one to two years of the onset of symptoms (Gajdusek, 1957).

The World Health Organization (WHO) has published guidance on case classification and surveillance standards for vCJD and other human-transmissible prion diseases (WHO, 2003).

Animal

There are a number of known prion diseases in animals:

Bovine spongiform encephalopathy (BSE):

BSE is a type of prion disease that affects cows. The first cases were identified in the mid-1980s, but BSE didn't gain widespread attention until a major outbreak in the United Kingdom later that decade into the 1990s. Millions of cows were infected.

By 2005, 24 countries had reported BSE among native cattle. (20 of the 24 were in Europe).

The spread of infection in cattle was likely tied to feeding practices. It is speculated that it is related to cows being fed meat and bone meal from other cows that had prion disease (CDC, 2024).

Chronic Wasting Disease (CWD):

CWD is a prion disease that affects animals like deer, elk, moose, and reindeer. It has been found in the United States, Canada, Norway, Finland, and Sweden. Imported cases have also been reported in South Korea. Though there have been no cases of CWD in people, experts think it poses a theoretical risk to people. This is because CWD is related to BSE, which has caused disease in people. If CWD could spread to people, hunters and people who eat meat from CWD-infected animals would likely be most at risk (CDC, 2024).

Scrapie:

The term scrapie encompasses two different pathological entities: classical and atypical scrapie. Both conditions are chronic, neurodegenerative, fatal diseases of sheep and goats and are caused by similar agents. However, they differ in clinical presentation, pathogenesis, pathology, biochemical properties and epidemiology. Classical scrapie is characterised by vacuolar changes in the central nervous system (CNS). It has been recognised as a clinical disorder for more than 250 years and is classified as a transmissible spongiform encephalopathy (TSE), or prion disease, as defined by the accumulation of an abnormal form of a host cell membrane-bound glycoprotein (prion protein or PrP) referred to as PrPSc, in the CNS. Polymorphisms of the PrP gene are associated with susceptibility to scrapie. The more recently identified condition known as atypical scrapie has some clinical and pathological features similar to classical scrapie but is not considered to be transmitted in field situations. The epidemiology is consistent with a non-contagious condition that occurs sporadically. Classical scrapie may be transmitted from dam to offspring in the period from parturition to weaning, and in utero. It can also be transmitted horizontally to unrelated sheep or goats. The infectious material can persist for several years in pastures and in buildings. Foetal membranes are a source of infection, and milk from clinically affected animals can transmit disease. The incubation time between primary infection and clinical disease is usually longer than 1 year and may sometimes exceed the commercial lifespan of the animal. The majority of cases occur between 2 and 5 years of age. Clinical disease develops only if the agent enters the CNS. Atypical scrapie, where it presents clinically, is reported mostly in older animals, and occurs with a geographical distribution suggestive of a spontaneous disease, although it has been transmitted experimentally. There are no vaccines available. There is no evidence of a causal link between classical or atypical scrapie and human TSEs (WOAH, no date).

Metrics and numeric limits

Not available

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Acquired human prion diseases are rare. In these instances, the most common outside sources are either medical procedures, where an individual may be exposed to the abnormal prion protein via contaminated equipment or certain transplanted human tissues, or via ingestion of meat from cattle infected with BSE (linked to vCJD). Other prion diseases such as scrapie and chronic wasting disease can be transmitted between animals, however transmission from animals to humans has only been observed in BSE/vCJD (WHO, 2003).

There is also concern about the possibility that bovine-derived materials involved in the production of vaccines and other pharmaceutical products could represent a way of potential transmission of the disease. Foetal calf serum is a widespread component of growth media, and other media components such as enzymes, and hormones are extracted from cattle. Additionally, bovine materials have been used in a variety of materials such as gelatine, a component of capsules. An intense regulatory effort has therefore been made to eliminate materials potentially contaminated with BSE from all stages of production. Where bovine materials are still required, they must be sourced from geographical areas that are not endemic for BSE. In addition, difficult regulatory

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decisions have been necessary where the relative risks inherent in replacing fully characterized materials (such as vaccine seed strains) are compared with the mathematically small risk of vCJD transmission. The field is also complicated by the difficulty in assaying materials for TSEs, and in conducting studies to detect major routes of transmission and infection of this highly novel class of pathogen (WHO, no date)

In 2006 a WHO report stated that the eventual impact of human exposures to BSE agent and secondary transmissions of vCJD via blood, blood components and plasma-derived products cannot be predicted (WHO. 2006). It also reported that blood programs and national authorities should consider carefully, in advance, the potential impact of screening donors for TSE—including the implications of notification for persons testing positive, their families and society, as well as on the blood supply (WHO, 2006).

Impacts: Bovine spongiform encephalopathy (BSE) is a progressive, fatal disease of the nervous system of bovines that is caused by the accumulation of an abnormal protein called 'prion' in nervous tissue. Two forms can be distinguished: classical BSE (caused by C-type BSE agent), which occurs in bovines after ingesting prion-contaminated feed, and atypical BSE (caused by H- and L-type agents), which is believed to occur spontaneously in all bovine populations. Classical BSE was first detected in 1986, and the implementation of appropriate control measures resulted in its decline worldwide. To date, the incidence of both forms is negligible and estimated to approach zero cases per million bovines. Classical BSE is considered zoonotic due to its assumed link with the emergence of variant Creutzfeldt-Jakob disease in humans. Classical BSE is a WOAH-listed disease, for which WOAH has established official recognition of sanitary risk status (WOAH, 2023).

Multi-hazard Context: Concern about iatrogenic (i.e. illness caused by medical examination or treatment) spread of prion-related disease from the use of contaminated corneal and dura mater grafts, neurosurgical equipment, and cadaver-derived human growth hormone and bloodborne transmission of vCJD has long been suspected as possible because of some unusual features of the disease (Belay & Schonberger, 2005).

Monitoring: WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date).

Risk Management: In order to update the preventive measures proposed by the World Health Organization (WHO) in 1997 to minimize the risks associated with the use of vaccines, blood products and other pharmaceutical products containing bovine-derived and human-derived materials, a meeting of international experts was convened at WHO in Geneva on 3-5 February 2003. The purpose was to review the latest available data on the epidemiology, antemortem and post-mortem diagnosis, detection of the infectious agents, and distribution of infectivity in tissues or body fluids of relevant species with TSEs (WHO, 2003)

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Coordinating agency or organisation

World Health Organization. United Nations Food and Agriculture Organization

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BI0231 / BIOLOGICAL / Infectious Diseases (Human and Animal)

zoonosis

Q Fever

Definition

Q fever is a common zoonosis (infection that could transmit from animals to humans), caused by *Coxiella burnetii*. Natural reservoirs include several domestic and wild animals, most of which show no signs of disease (although infection can cause abortions). Due to the high resilience in the environment of Coxiella, humans are most often infected by inhalation of aerosols produced in contaminated locations, but other modes of infection have been documented (including food-borne) (ECDC, no date).

Reference

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Annotations

Synonyms

Query Fever, Coxiellosis, Abattoir fever, *Coxiella burnetii* fever, Q fever pneumonia, Queensland fever, Nine mile fever, American Q fever, Australian Q fever.

Additional scientific description

Q fever was first recognised as a human disease in Australia in 1935 and in the USA in the early 1940s. The 'Q' stands for 'query' and was applied at a time when the cause was unknown (CDC, 2024).

Q fever is a zoonotic disease caused by infection with *Coxiella burnetii* that affects humans and other animals. *C. burnetii* is uncommon but may be found in cattle, sheep, goats, and other domestic mammals, including cats and dogs. Clinical cases seem to be most significant in sheep and goats, with sporadic losses and occasional outbreaks that may affect up to 50-90% of the herd. The infection results from inhalation of a spore-like small-cell variant, and from contact with the milk, urine, faeces, vaginal mucus, or semen of infected animals. Rarely, the disease is tick-borne (Spickler, 2017).

Humans are vulnerable to Q fever, and infection can result from even a few organisms. Some people never get sick; however, those who do usually develop flu-like symptoms including fever, chills, fatigue, and muscle pain (CDC, 2024). The main way of reducing the risk of being infected with Q fever is by avoiding contact with infected animals, especially while animals are giving birth. Be aware that animals can be infected with *C. burnetii* and appear healthy. People in direct contact with animals during birthing, such as veterinarians and farmers, may be at higher risk for infection. Abattoir workers are also at risk while being in contact with infected carcasses (Spickler, 2017).

Coxiella burnetii can survive for long periods in the environment and may be carried long distances by wind. Windborne outbreaks can affect dozens to hundreds of people who have no direct exposure to animals. In one exceptional incident, more than 4000 clinical cases were recognised in the Netherlands between 2007 and 2010. Efforts to end this outbreak resulted in temporary breeding bans and the culling of more than 50,000 small ruminants. The current state of knowledge about *C. burnetii* is incomplete, and some aspects of infections in humans and animals are still debated or not well understood (Spickler, 2017).

Coxiella burnetii has been found in most countries that have conducted surveillance. However, a few countries or areas, such as New Zealand, Norway, Iceland and French Polynesia, report that they have not found any evidence of this organism in surveys to date (Spickler, 2017).

Human
The incubation period for acute Q fever ranges from two days to six weeks, with most patients becoming ill within two to three weeks of exposure. Chronic Q fever is reported to develop months to years after infection, although some of the latter cases could result from delayed diagnosis. Studies from recent outbreaks in the Netherlands suggest that most cases of endocarditis can be detected within a few months to a year of infection (Spickler, 2017).
Animal
Q fever is a widespread disease caused by the bacteria *Coxiella burnetii*, which can infect mammals e.g. cattle, sheep, goats, donkeys, camels, fowl, dogs, cats, birds, reptiles and arthropods. Animal vaccination has been used in areas where infections are common. Most countries maintain a list of approved veterinary vaccines for use. For specific regulations, consult the country's veterinary authorities. Q fever is mostly associated with sporadic abortions or outbreaks of abortions and dead or weak offspring in cattle, sheep, and goats. Infection persists for several years. Sheep, goats and cows are mainly subclinical carriers but can shed bacteria in various secretions and excreta. Q fever is also transmitted by inhalation or dust contaminated with infected animal secreta or excreta. Q fever can also be spread by ticks which pass the bacteria from an infected to a susceptible animal, whose faeces contain the bacteria thus also contaminating the environment. Humans generally acquire infection through air-borne transmission from animal reservoirs, especially from domestic ruminants, but other domestic and wildlife animals (pets, rabbits, birds, etc.) can be involved. *C. brunetii* displays different morphological forms in its developmental cycle, and some of the forms can survive extracellularly and even accumulate in the environment (FAO, 1994; WOAH, 2024a).

Metrics and numeric limits

Q fever was made a nationally notifiable disease in the United States in 1999. CDC compiles the number of cases reported by state and local health departments and reports national trends. The number of Q fever cases reported to CDC increased, from 19 cases reported in 2000 to 173 cases reported in 2007. In 2008, the Q fever case definition was changed to allow for the reporting of chronic and acute Q fever separately. During 2008-2013 the number of reported cases decreased slightly, relative to 2007, returning to high levels in 2014. In 2019, 178 acute Q fever cases were reported, as well as 34 chronic Q fever cases. (CDC, 2024b)

For 2019, 1 069 cases of Q fever were reported in the European Union/European Economic Area (EU/EEA), 958 (90%) of which were confirmed (ECDC, 2021)

Key relevant UN convention / multilateral treaty

Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction (UNODA, no date).

International Health Regulations (2005), 3rd ed. (WHO, 2016).

WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) (WTO, 1994).

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Examples of hazard drivers, impacts and risk management

Hazard Drivers and Impacts

Human
Hazard Drivers: Introduction of infected animals, contaminated environment, dust, consumption of contaminated products **Impacts:** abortions late in the pregnancy, infect humans Anybody who works with cattle, sheep or products produced from them is at an increased risk of catching Q fever, including the following occupations: farm workers, slaughterhouse workers, workers in meat-packing plants, veterinarians and wool workers. Severe disease has been reported in the foetus; therefore, pregnant women are at risk of passing the infection on to their babies. The disease can also be particularly severe in newborn babies. People who have problems with their heart valves are at increased risk of contracting endocarditis (inflammation of the inner lining of the heart) (ECDC, no date).
Animal
Hazard Drivers: introduction of infected animal, contaminated environment, dust, consumption of contaminated products **Impacts:** abortions late in the pregnancy, infect humans

Multi-hazard Context: Many factors influence Q fever outbreaks which can manifest in a variety of settings and with differing epidemic patterns. Q fever is commonly perceived as a hazard to persons working with livestock, but an absence of animal contact does not preclude infection due to the marked capacity for indirect transmission, leading to the likely underestimation of risk for outbreaks in urban communities. Lack of suspicion for Q fever in these populations can lead to difficulties in outbreak recognition and consequently delay a response (Tan et al, 2023).

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Monitoring: The table below offers an overview of monitoring for Q fever in animals. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	WHO, Ministry of Health, Ministry of Agriculture, Ministry of Livestock, FAO Reference Centres, WOAH Reference Centres
How is the Hazard Observed/Monitored/Forecast?	Through its global early warning system, FAO has been supporting Members with risk monitoring, assessment and forecasting for animal health threats to enhance preparedness and response to animal health threats: • The Global Animal Disease Information System, EMPRES-i+, plays a crucial role in supporting countries with early warning and early detection of animal disease outbreaks. By providing a comprehensive platform for real-time disease tracking, EMPRES-i+, enables monitoring and analysis of animal health threats effectively, collaborating closely with countries and regions on disease information sharing. This supports the dissemination of risk assessments and alerts for evidence-based decision-making. • FAO develops and maintains decision support tools that provide risk maps of existing and predicted risks of animal disease emergence, as well as other threats to the agri-food chain. • Additionally, FAO collaborates closely with international organizations like WHO and WOAH to verify disease information through integrated mechanisms such as the Epidemic Intelligence from Open Sources (EIOS), the Global Early Warning System (GLEWS+), and the World Animal Health Information System (WAHIS) for WOAH-listed diseases. These collaborations allow for the dissemination of early warning alerts and risk assessments to Members, to enable timely responses to potential outbreaks. FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country's risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date).

Risk Management

Human
Risk Management: ECDC recommends good hygiene practices on premises dealing with animals—particularly with sheep, cattle and goats—will help prevent transmission of the bacteria that causes Q fever. As the disease can be transmitted to humans through contaminated milk, pasteurisation of milk and milk products will help prevent infection (ECDC, no date). Additionally, other risk management can in summary include movement control, treatment with antimicrobials, tracing back/forward and vaccination.
Animal
Risk Management*:* Animal vaccination has been used in areas where infections are common. More generally, sanitary measures to remove after-birth and birth fluids, and to clean and disinfect areas where animals have given birth can prevent the disease from spreading (WOAH, 2024a; 2024b; no date). Other actions include movement control, treatment with antimicrobials, tracing back/forward, and vaccination (prevention).

Preliminary – Corrections Pending

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Coordinating agency or organisation

Food and Agriculture Organization of the United Nations (FAO), World Health Organization (WHO), World Organisation for Animal Health (WOAH).

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BI0232 / BIOLOGICAL / Infectious Diseases (Human and Animals)

zoonosis

Rabies (Animal and Human)

Definition

Rabies is a serious public health problem in over 150 countries and territories. It is a viral zoonotic disease that affects the central nervous system and spreads from bites, licks, and scratches from infected mammals. It is almost always fatal when clinical signs appear, killing approximately 59,000 people every year (adapted from WHO, 2024a; and WOAH no date).

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Annotations

Synonyms

Rage (fr), Rabia (es).

Additional scientific description

Human

Rabies is caused by the rabies virus in the family *Rhabdoviridae* and the genus *Lyssavirus*. It is a zoonotic disease, (an infectious disease which spreads from humans to animals) and probably the oldest known infectious disease of people. Rabies is a serious public health problem (WHO, 2024a).

Tens of thousands of people die from rabies each year. Rabies is a fatal but preventable infectious disease. Human rabies is preventable via thorough wound washing, administration of a course of human rabies vaccine and, when indicated, rabies immunoglobulins (RIG) (WHO, 2024a)

In up to 99% of human rabies cases, dogs are responsible for virus transmission. Children between the ages of 5 and 14 years are frequent victims (WHO, 2024a).

Rabies is transmitted through inoculation of infectious saliva via a bite (most common), scratch, or direct contact with mucosa (e.g. eyes, mouth, or open wound). This causes local muscle infection and then uptake by peripheral nerves where it spreads to the central nervous system and replicates in the brain prior to spreading to salivary glands and being excreted in saliva (WHO, 2024a).

Vaccinating people and dogs saves lives and stops transmission. Rabies in people can be prevented through dog bite prevention, wound washing, and post-exposure prophylaxis. Rabies in dogs can be prevented through responsible dog ownership and routine mass dog vaccination (WHO, 2024a).

Clinically rabies is characterized by an incubation phase, a prodromal phase and then a neurological phase which precedes death. In humans, following exposure, the incubation period is usually 4-12 weeks (but may range from < 1 week to > 12 months). Rabies is almost always fatal once clinical signs appear. This is followed by a prodromal phase of generic symptoms such as fever, malaise, fatigue, headaches, loss of appetite and tingling at the wound site. Their neurological phase consists of two distinct clinical forms, furious and paralytic. The furious form is characterized by hyperactivity, hallucinations, aerophobia, hydrophobia, excessive salivation, and aggression and usually lasts 5 days. The paralytic form is characterized by progressive paralysis and coma and usually lasts up to 14 days (WHO, 2018a).

An estimated 59,000 people die each year from rabies; however, this number is likely a gross underestimate due to underreporting and uncertain estimates. It can be misdiagnosed as another viral encephalitis or cerebral malaria, many deaths occur at home, surveillance is inadequate, and it commonly affects poor, rural communities which are commonly underserved.

Currently, there are no WHO-approved diagnostic tools for detecting rabies infection before the onset of clinical disease. Clinical diagnosis of rabies is difficult without a reliable history of contact with a rabid animal or specific symptoms of hydrophobia or aerophobia. Accurate

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risk assessment is crucial for deciding on PEP administration (WHO, 2024a). Once symptoms emerge, and death is inevitable, offering comprehensive and compassionate palliative care is recommended. Post-mortem confirmation of rabies infection is done by various diagnostic techniques that detect whole viruses, viral antigens, or nucleic acids in infected tissues (brain, skin or saliva) (WHO, 2024a). Where possible, the biting animal should be tested (WHO, 2024a).

Wound washing as soon as possible after exposure for 15 minutes with copious amounts of soap and water is the first life-saving measure following exposure. A detailed assessment should be conducted to determine PEP eligibility, including an assessment of the health status of the biting animal, wound category and if the patient has already received rabies vaccine. Pre-exposure prophylaxis shortens but does not replace post-exposure prophylaxis, WHO has produced a decision tree to aid this process (WHO, 2024b; WHO 2024a PEP should be started as soon as possible following exposure; it is never too late to administer PEP. Pre-exposure prophylaxis vaccine is recommended for high-risk individuals such as communities and travellers in remote, highly endemic settings and individuals at occupational risk. WHO prequalified vaccines are safe, effective, and well tolerated (WHO, 2024a). There are a number of approved vaccine schedules, however, intra-dermal vaccination is recommended as it saves costs, doses and time (WHO, 2018b). Rabies immunoglobulin (RIG) is recommended for severe exposure for those who have not previously received rabies vaccines.

Since rabies is widespread in most of the world and across many animal species, it is very difficult to eradicate but: domestic dogs play a crucial role in the transmission of rabies to other species.

Rabies elimination requires a One Health approach. Human and dog rabies are correlated. Addressing rabies at its source – dog rabies -is the most efficient and cost-effective way to break transmission. The World Health Organization (WHO), the World Organization for Animal Health (WOAH), the Food and Agricultural Organization of the United Nations (FAO) and the Global Alliance for Rabies Control have united to deliver Zero by 30: The Global Strategic Plan to Prevent Human Deaths from Dog-Transmitted Rabies by 2030. It provides a coordinated response using a three-pillar approach: increasing availability of human post-exposure prophylaxis, awareness and community engagement and mass dog vaccination. This aligns with the United Nations Sustainable Development Goals through strengthening human and veterinary health systems to reach the world's most underserved populations (WHO, FAO and OIE, 2018).

Community engagement is fundamental to the success of mass dog vaccination; local communities are key stakeholders. Rabies elimination happens at community level. Awareness activities must target vulnerable populations.

Animal

Rabies is a viral disease that affects the central nervous system of mammals (dogs, cats, foxes etc.) (WOAH, no date). Rabies is preventable through vaccination (Rupprecht & Gatewood, 2021). While 99% of human rabies cases are due to bites from infected dogs, rabies vaccines for dogs can efficiently eliminate the disease at its animal source (WOAH, no date). Most countries maintain a list of approved veterinary vaccines for use. For specific regulations, consult the country's veterinary authorities.

Rabid dogs are infective even when their clinical signs are still mild. Notably in dogs, the furious form is characterized by altered behaviour, aggression, incoordination, drooping jaw and altered tone of bark. There is an absence of aerophobia and hydrophobia in dogs (WOAH, 2024a; WOAH, 2024b)). Rabid cats can attack suddenly, biting and scratching viciously. As the disease progresses, seizures and lack of muscle coordination are common. Death is caused by progressive paralysis (MSD, 2024). In the Americas, bat species are also reservoirs for rabies virus (WHO, 2024).

Clinical signs in affected wildlife can be variable and subtle. A common and important feature is a change in behaviour including a loss of fear, ataxia, and subsequent aggression towards other animals and people. Wild animals will often lose their natural caution around humans. Animals may wander into urban areas and into buildings. Abnormal appetite (pica) and unusual vocalisation, which is often incessant. Excitation is often seen and may present as ceaseless running over long distances, with or without snapping at nearby objects, animals or people. A rabid fox may charge at and bite passing people, animals and even vehicles. Paralysis, paresis and, in the terminal stages, coma occur (Wildlife Health Australia, 2024).

There are many strains of the rabies virus maintained in particular reservoir hosts. These include Canidae (dogs, jackals, coyotes, wolves, foxes and raccoon dogs), Mustelidae (skunks, martens, weasels and stoats), Viverridae (mongooses and meerkats), Procyonidae (raccoons), and the order Chiroptera (bats). The important reservoir hosts vary with the area. Cat-adapted rabies variants have not been seen, although cats are often infected with rabies viruses from other hosts, and they can readily transmit the virus (CFSPH et al., 2009).

Metrics and numeric limits

An estimated 59,000 people die of rabies every year in over 150 countries, approximately 99% are acquired from the bite of an infected dog. 95% of human cases occur in Africa and Asia. Due to underreporting and uncertain estimates, this number is likely a gross underestimate. The burden of disease is disproportionally borne by rural poor populations, with approximately half of cases attributable to children under 15 years of age (WHO, 2024a).

The global cost of rabies is estimated to be around US$ 8.6 billion per year including lost lives and livelihoods, medical care and livestock losses, as well as uncalculated psychological trauma (WHO, 2024a).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Quadripartite Collaboration for One Health, 2022 (FAO, UNEP, WHO & WOAH).

One Health High-Level Expert Panel (OHHLEP) (2021) (FAO, UNEP, WHO & WOAH).

United Nations. 2023. UN Recommendations on the Transport of Dangerous Goods - UN Model Regulations. (UNECE, 2023)

Preliminary – Corrections Pending

Examples of hazard drivers, outcomes and risk management

Hazard drivers and impacts

Human
Hazard Drivers: Children are at greater risk than adults as they are more likely to play with animals, not to report bites, may receive more severe bites and due to their size are more often bitten on the head or receive multiple bites. These factors increase the risk of being bitten, not receiving immediate medical care and the infection spreading to the brain more quickly. In the Americas, where dog-mediated rabies is mostly controlled, hematophagous (blood-feeding) bats are now the primary source of human rabies. Bat-mediated rabies is also an emerging public health threat in Australia and parts of Western Europe. Human deaths following exposure to foxes, raccoons, skunks, and other wild mammals are very rare, and bites from rodents are not known to transmit rabies. Contraction of rabies through inhalation of virus-containing aerosols, consumption of raw meat or milk of infected animals, or through organ transplantation is extremely rare (WHO, 2024a). **Impacts:** Rabies has the highest case fatality rate of any currently recognised infectious disease. It is an indicator of the impact on inequity, the capacity of the health system and One Health. Rabies is present in mammals in most parts of the world. It is one of the Neglected Tropical Diseases (NTD) that predominantly affects poor and vulnerable populations who live in remote rural locations. The large majority of the estimated 59,000 human deaths from rabies per year occur in Africa and Asia, (WHO, 2024a).
Animal
Hazard Drivers: Carnivores, especially of the *Canidae* family represent the principal reservoir species and are responsible for the maintenance of the infectious cycle and hence for the presence of the disease. While wildlife rabies maintained by different reservoir hosts predominantly occurs in the Northern Hemisphere, canine rabies is by far more important for public health. **Impacts**: Deaths of humans and animals including livestock (rabies is a fatal disease of mammals).

Multi-hazard Context: Not applicable.

Monitoring: The table below offers an overview of monitoring for rabies. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Ministry of Health, WHO, Ministry of Agriculture, Ministry of Livestock, FAO Reference Centres, WOAH Reference Centres
How is the Hazard Observed/Monitored/Forecast?	Through its global early warning system, FAO has been supporting Members with risk monitoring, assessment and forecasting for animal health threats to enhance preparedness and response to animal health threats: • The Global Animal Disease Information System, EMPRES-i+, plays a crucial role in supporting countries with early warning and early detection of animal disease outbreaks. By providing a comprehensive platform for real-time disease tracking, EMPRES-i+, enables monitoring and analysis of animal health threats effectively, collaborating closely with countries and regions on disease information sharing. This supports the dissemination of risk assessments and alerts for evidence-based decision-making. • FAO develops and maintains decision support tools that provide risk maps of existing and predicted risks of animal disease emergence, as well as other threats to the agri-food chain. • Additionally, FAO collaborates closely with international organizations like WHO and WOAH to verify disease information through integrated mechanisms such as the Epidemic Intelligence from Open Sources (EIOS), the Global Early Warning System (GLEWS+), and the World Animal Health Information System (WAHIS) for WOAH-listed diseases. These collaborations allow for the dissemination of early warning alerts and risk assessments to Members, to enable timely responses to potential outbreaks. FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country's risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021a).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date).

Preliminary – Corrections Pending

Risk Management:

Human
Risk Management: Traditional medicine, faith healing and alternative medicine cannot prevent or cure rabies. It does not substitute life-saving PEP and can often delay it. Healers can help people cope with their illness and may be the only option in marginalized areas, so dialogue and cooperation with healers is recommended to increase compliance with PEP. In June 2024 Gavi announced its support for human rabies vaccines for post-exposure prophylaxis (PEP) within routine immunisation. This "complements ongoing global efforts" of the Zero by 30 campaign, led by the United Against Rabies Forum, seeking to eliminate all dog-mediated human rabies deaths by 2030. Gavi's support is incremental, it only adds to but does not replace domestic funding. It helps to accelerate existing rabies programs (WHO, 2024a).
Animal
Risk Management: Dog vaccination is the most cost-effective way to prevent rabies. Vaccinating 70% of the susceptible dog population stops transmission. Mass dog vaccination controls canine rabies eliminates dog-mediated human rabies deaths, safeguards those who struggle to access PEP and protects the lives of livestock and the livelihood of rural communities (WHO, 2021b). Indiscriminate dog culling is ineffective because the dog population will inevitably bounce back, and counterproductive as vaccinated dogs can get killed. It is not favourable to communities who may then choose to relocate their dogs. Mass dog vaccination must target free-roaming dogs who contribute the most to transmission. Puppies must be included in the campaigns, and a mixed-method approach is acquired to reach targets. Each dog should be re-vaccinated every 1 -2 years. Identification of vaccinated dogs can be through either collars, temporary paint or vaccine certificates. Cross-border dog vaccination campaigns are key as rabies does not recognize country borders (WHO, 2022). Oral vaccination may target hard-to-catch dogs but must be assessed for safety. Oral vaccination has eliminated fox, coyote, and raccoon rabies in the Northern Hemisphere. Reducing dog density has many benefits but is not necessary to eliminate rabies. Dog population management through dog ownership, dog confinement practices etc. is key to rabies elimination. Along with vaccination, awareness is the key to eliminating dog-mediated rabies. Along with the Zero by 30 campaign, communication materials in various languages are available (GARC, no date).

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Coordinating agency or organisation

World Health Organization (WHO) for rabies in humans, Food and Agriculture Organization of the United Nations (FAO) and World Organisation for Animal Health (WOAH) for rabies in animals.

Preliminary – Corrections Pending

BI0233 / BIOLOGICAL / Infectious Diseases (Human and Animal)

zoonosis

Rotavirus (Human)

Definition

Rotaviruses are the most common cause of severe diarrhoeal disease in young children throughout the world. According to WHO estimates in 2013 about 215,000 children aged under 5 years die each year from vaccine-preventable rotavirus infections; the vast majority of these children live in low-income countries (WHO, 2018).

Reference

WHO, 2018. Rotavirus. World Health Organization (WHO). https://www.who.int/teams/health-product-policy-and-standards/standards-and-specifications/norms-and-standards/vaccines-quality/rotavirus Accessed 17 February 2025.

Preliminary – Corrections Pending

Annotations

Synonym

Rotavirus infection. Diarrhoeal disease

Additional scientific description

Rotavirus, a member of the reovirus family, causes watery diarrhoea, vomiting and severe dehydration in young children. Rotavirus is common, accounting for 35-60% of acute severe diarrhoea in children less than 5 years of age in countries without rotavirus vaccine, with the highest attributable percentage in infants. Rotavirus diarrhoea is ubiquitous, and children are infected at an early age. It often causes nosocomial outbreaks in paediatric wards where handwashing and other infection prevention and control measures are lax (WHO, no date a).

Rotavirus is the most common cause of severe diarrhoeal disease in infants and young children globally. It is transmitted through the oral-faecal route, directly from person to person, or indirectly through contaminated objects. People who are infected experience an abrupt onset of fever and vomiting followed by explosive, watery diarrhoea. Rotavirus diarrhoea is profuse, often leading to dehydration which can be severe, requiring hospitalization. The most severe threat posed by diarrhoea is dehydration (WHO no date a). The cornerstones of treatment of severe rotavirus diarrhoea are fluid replacement and zinc supplementation (WHO, no date a).

Vaccines against rotavirus are available, and vaccination is an important measure to reduce severe rotavirus-associated diarrhoea and mortality (WHO, no date a).

Rotavirus causes watery diarrhoea, vomiting and severe dehydration in young children. Rotavirus diarrhoea is ubiquitous and, unlike bacterial diarrhoea, is not more prevalent in settings with poor water, sanitation and hygiene. Rotavirus peaks in cool, dry seasons in temperate climates but exhibits less pronounced seasonality in tropical settings (WHO, no date a).

The clinical spectrum of rotavirus disease is wide, ranging from transient loose stools to severe diarrhoea and vomiting causing dehydration, electrolyte disturbances, shock, and death if rehydration is not provided. In typical cases, following an incubation period of 1-3 days, the onset of disease is abrupt, with fever and vomiting followed by watery diarrhoea. Gastrointestinal symptoms normally resolve within 3-7 days but may last for up to 2-3 weeks (WHO, no date a).

The World Health Organization (WHO) has published guidance on case classification and surveillance standards (WHO, 2018a).

Metrics and numeric limits

Rotavirus has a case-fatality rate (CFR) of approximately 2.5% among children in developing countries who present to health facilities. This CFR is higher in areas without good access to health care. In 2013, rotavirus caused an estimated 215 000 deaths worldwide (WHO, 2018b).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Rotaviruses are shed in very high concentrations and for many days in the stools and vomitus of infected individuals. Transmission occurs primarily by the faecal-oral route, directly from person to person or indirectly via contaminated fomites. The universal occurrence of rotavirus infections shows that clean water supplies and good hygiene are unlikely to have a substantial effect on virus transmission (WHO, no date a).

Rotaviruses are the most common cause of severe diarrhoeal disease in infants and young children worldwide. Studies estimate that approximately 200,000 people die annually from infection. In their systematic review and Bayesian multinomial review, Black et al. (2024) reported that diarrheal diseases leading to the largest estimated global attribution was rotavirus; in LMICs, the proportion of deaths from diarrhoea due to rotavirus in children younger than 5 years appeared lower in 2021 (108 322 [24·4%] of 443 342, 95% uncertainty interval 21·6-29·5) than in 2000 (316 382 [26·5%] of 1 196 134, 25·7-28·5), but the 95% CIs overlapped (Black et al, 2024).

Although the infection rate has decreased with the advent of vaccines, infections are still common throughout the world. Although the viral strains show considerable diversity, 5 serotypes are responsible for the majority of human rotavirus disease. Primarily transmitted by the faecal-oral route, rotaviruses affect the vast majority of children worldwide before the age of 3 years, and in most developing countries before the first birthday (WHO, no date a).

Impacts: Rotavirus has a case-fatality rate of approximately 2.5% among children in low-income countries who present to health facilities. This rate is higher in areas without good access to health care (WHO, no date a). Published in 2003, a peer-review publication reported that each year, rotavirus causes an estimated 111 million episodes of diarrhoea requiring only home care, 25 million clinic visits, 2 million hospitalizations, and 352,000-592,000 deaths (median 440,000 deaths) in children <5 years of age. In other words, by 5 years of age, almost all children will have an episode of rotavirus gastroenteritis, 1 in 5 will require a clinic visit, 1 in 60 will require hospitalization, and approximately 1 in 293 will die. The incidence of rotavirus disease is similar in children in both developed and developing nations. However, children in developing nations die more frequently, possibly because of several factors, including poorer access to hydration therapy and a greater prevalence of malnutrition. An estimated 1,205 children die from rotavirus disease each day, and 82% of these deaths occur in children in the poorest countries (Parashar et al., 2003).

Multi-hazard Context: Not Applicable.

Monitoring: WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country's risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date a).

Risk Management: WHO prequalified rotavirus vaccines have been available since 2008 and there are currently four vaccines available. They are all live, oral vaccines. RotaTeq, Rotavac, and ROTASIIL should be administered in a 3-dose schedule, while a 2-dose schedule should be used for Rotarix. A minimum interval of 4 weeks should be maintained between doses (WHO, no date a).

WHO recommends that rotavirus vaccines should be included in all national immunization programmes and considered a priority, particularly in countries with high rotavirus gastroenteritis-associated fatality rates, such as in South and South-eastern Asia and sub-Saharan Africa (WHO, no date a).

In addition, key measures to prevent diarrhoea include the following:

- access to safe drinking water
- use of improved sanitation
- hand washing with soap
- exclusive breastfeeding for the first six months of life
- good personal and food hygiene
- health education about how infections spread (WHO, no date a)

Black et al. (2024) indicate progress in the reduction of deaths from diarrhoea caused by 12 pathogens in children younger than 5 years in the past two decades. However, they recommend that there is a need to increase efforts for prevention, including with rotavirus vaccine, and treatment to eliminate further deaths (Black et al, 2024).

Preliminary – Corrections Pending

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0234 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Shigellosis (Human)

Definition

Shigellosis is an acute invasive enteric infection caused by bacteria belonging to the genus Shigella and is estimated to cause at least 80 million cases of bloody diarrhoea and 700,000 deaths each year (WHO, 2005).

Reference

WHO, 2005. Guidelines for the control of shigellosis, including epidemics due to Shigella dysenteriae type 1. World Health Organization (WHO). https://www.who.int/publications/i/item/9241592330 Accessed 08 March 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Bacillary Dysentery; Dysentery; Shigella Dysenteries; *Shigella boydii* Dysentery; *Shigella sonnei* Dysentery; Shigella flexneri Dysentery.

Other synonyms are available here.

Additional scientific description

Shigellosis is clinically manifested by diarrhoea that is frequently bloody. Other common symptoms are abdominal cramps and tenesmus (unproductive, painful straining), fever and loss of appetite (WHO, 2005). The majority of cases and deaths are among children less than five years of age (WHO, 2005).

Shigellosis is endemic in many developing countries and also occurs in epidemics causing considerable morbidity and mortality. It is estimated to cause at least 80 million cases of bloody diarrhoea and 700,000 deaths each year (WHO, 2005). Ninety-nine percent of infections caused by Shigella occur in developing countries, and the majority of cases (~70%), and deaths (~60%), occur among children less than five years of age). Probably less than 1% of cases are treated in hospital (WHO, 2005).

Shigella are Gram-negative, non-motile bacilli belonging to the family Enterobacteriacae. The genus Shigella includes four species: S. *dysenteriae*, *S. flexneri*, *S. boydii* and *S. sonnei*, also designated groups A, B, C and D, respectively. The first three species include multiple serotypes. *S. sonnei* and *S. boydii* usually cause relatively mild illness in which diarrhoea may be watery or bloody. S. *flexneri* is the chief cause of endemic shigellosis in developing countries. Immunity is serotype-specific. Among the four species of Shigella, *Shigella dysenteriae* type 1 (Sd1) is especially important because it causes the most severe disease and may occur in large regional epidemics. Major obstacles to the control of shigellosis include the ease with which Shigella spreads from person to person and the rapidity with which it develops antimicrobial resistance (WHO, 2005).

All species of Shigella cause acute bloody diarrhoea by invading and causing patchy destruction of the colonic epithelium. This leads to the formation of micro-ulcers and inflammatory exudates and causes inflammatory cells (polymorphonuclear leucocytes, PMNs) and blood to appear in the stool. The diarrhoeal stool contains 106-108 Shigellae per gram. Once excreted, the organism is very sensitive to environmental conditions and dies rapidly, especially when dried or exposed to direct sunlight (WHO, 2005).

Although most infections with *S. sonnei* result in a short duration of disease and low case fatality, multi-drug resistant (MDR) and XDR shigellosis is a public health concern since treatment options are very limited for moderate to severe cases (WHO, 2022).

Definitive diagnosis can only be made by isolating the organism from stool and serotyping the isolate. Culture is also required to determine antimicrobial sensitivity (WHO, 2005).

The World Health Organization (WHO) has published guidance on case classification and surveillance standards (WHO, 2005).

Metrics and numeric limits

Among children younger than 5 years, it is estimated that diarrhoea is responsible for about 446 000 deaths, which are

geographically concentrated in sub-Saharan Africa and South Asia.

Shigella was the second-leading cause of diarrhoeal mortality in 2016 among all ages, and the leading bacterial cause of diarrhoea, accounting for approximately 212 000 deaths and about 13% of all diarrhoea-associated deaths (Khalil et al., 2018).

The greatest burden is among children in low- and middle-income countries (LMICs), where it is estimated to be responsible for between 28 000 (Maternal Child Epidemiology Estimation (MCEE) estimates) and 64 000 (Institute for Health Metrics and Evaluation (IHME) estimates) deaths among children under 5 years of age (Khalil et al., 2018; Lanata et al., 2013).

It is also an important cause of diarrhoea with or without dysentery in people older than 5 years, with an estimated 270 million episodes occurring annually among all ages. (WHO, no date a)

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Outbreaks of bloody diarrhoea due to Sd1 are most common in overcrowded, impoverished areas with poor sanitation, inadequate hygiene practices, and unsafe water supplies. Refugees and internally displaced persons are at especially high risk (WHO, 2005). It is spread by direct contact with an infected person, or by eating contaminated food or drinking contaminated water. Flies may also transmit the organism (WHO, 2005).

Shigellosis is endemic in most developing countries and is the most important cause of bloody diarrhoea worldwide. Some groups of people are more likely to get sick with shigellosis than others and include: children younger than 5 years old are the most likely to get shigellosis, but people of all ages can get the disease – with many outbreaks occur in early care and education settings and schools; travellers to places where water and food may be unsafe and sanitation is poor are more likely to get a Shigella infection - they are also more likely to become sick with types of Shigella that are more difficult to treat; gay, bisexual, and other men who have sex with men (GBMSM) have factors that put them at increased risk for Shigella infection – and although rates are higher among GBMSM, the risk is present for any sexual activity involving stool exposure; and people who are experiencing homelessness are at high risk for Shigella infection when there is shigellosis spread in the community – as they may face challenges in their living situations that increase the risk for disease transmission, which can result in outbreaks (CDC, no date).

Impacts: Prompt detection and reporting of cases of bloody diarrhoea is the essential first step in the monitoring of endemic shigellosis and in the control of epidemic shigellosis. The number of cases of bloody diarrhoea, and of deaths associated with bloody diarrhoea, should be determined and reported for two age groups: under five years, and five years or older. Each health facility should designate a specific individual to be responsible for reporting all cases of, and deaths associated with, bloody diarrhoea. Reports should be provided each week to the district health officer responsible for monitoring the occurrence of cases and detecting outbreaks. For surveillance and reporting purposes, the standard case definition of bloody diarrhoea or dysentery is 'diarrhoea with visible blood in the stool' (WHO, 2005).

Multi-hazard Context: Shigellosis is endemic in most developing countries and is the most important cause of bloody diarrhoea worldwide. Some groups of people are more likely to get sick with shigellosis than others and include: children younger than 5 years old are the most likely to get shigellosis, but people of all ages can get the disease – with many outbreaks occur in early care and education settings and schools; travellers to places where water and food may be unsafe and sanitation is poor are more likely to get a Shigella infection - they are also more likely to become sick with types of Shigella that are more difficult to treat; gay, bisexual, and other men who have sex with men (GBMSM) have factors that put them at increased risk for Shigella infection – and although rates are higher among GBMSM, the risk is present for any sexual activity involving stool exposure; and people who are experiencing homelessness are at high risk for Shigella infection when there is shigellosis spread in the community – as they may face challenges in their living situations that increase the risk for disease transmission, which can result in outbreaks (CDC, no date).

Monitoring: The geographical spread of XDR *S. sonnei* is under-reported. WHO advises national authorities to reinforce Shigella surveillance including testing for antimicrobial resistance to detect potential introductions to new areas and to prevent the establishment of local cycles of transmission in communities (WHO, 2022).

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country's risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance

Preliminary – Corrections Pending

system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date b).

Risk Management: Prevention relies on measures that prevent the spread of bacteria, such as handwashing, ensuring the availability of safe water, safe human waste disposal, breastfeeding of infants and young children, safe handling and processing of food and control of flies (WHO, 2005).

Treatment options for shigellosis include antimicrobials. The rise of antimicrobial-resistant enteric bacteria, particularly Shigella, means that, in addition to the potential direct effects on morbidity and mortality, a Shigella vaccine might also have indirect effects on reducing the use of antibiotics and the consequent emergence of antimicrobial resistance (AMR). Considering the potential for herd immunity and protection from all-cause diarrhoea, the development of a Shigella vaccine is an important goal for public health (WHO, no date).

Although several candidate *Shigella* vaccines are being evaluated at different stages of preclinical and clinical development, currently no licensed vaccines against *Shigella* diarrhoea are widely available. Development of *Shigella* vaccines has been identified as priority by the independent standing WHO committee of experts for the Product Development for Vaccines Advisory Committee (WHO, no date c) and WHO Preferred Product Characteristics (PPCs) (WHO, no date d) for a safe, effective and affordable vaccine to reduce mortality and morbidity due to dysentery and diarrhoea caused by *Shigella* in children under 5 years of age, in LMICs are being finalized (WHO, no date)

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0235 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Smallpox (Human)

Definition

Smallpox is an acute contagious disease caused by the variola virus. Before its eradication, smallpox was one of the world's most devastating diseases known and was fatal in up to 30% of cases (WHO, no date a).

Reference

WHO, no date a. Smallpox. World Health Organization (WHO). https://www.who.int/health-topics/smallpox#tab=tab_1 Accessed 27 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Variola, variola vera, pox, red plague.

Additional scientific description

Smallpox is an acute contagious disease caused by the variola virus, a member of the orthopoxvirus family. It was one of the most devastating diseases known to humanity and caused millions of deaths before it was eradicated. It is believed to have existed for at least 3000 years (WHO, no date a).

The smallpox vaccine, created by Edward Jenner in 1796, was the first successful vaccine to be developed. He observed that milkmaids who previously had caught cowpox did not catch smallpox and showed that a similar inoculation could be used to prevent smallpox in other people (WHO, no date a).

The World Health Organization launched an intensified plan to eradicate smallpox in 1967. Widespread immunization and surveillance were conducted around the world for several years. The last known natural case was in Somalia in 1977. In 1980 WHO declared smallpox eradicated – the only infectious disease to achieve this distinction. This remains among the most notable and profound public health successes in history (WHO, no date a).

Early symptoms of smallpox include high fever, fatigue, severe back pain, and less often, abdominal pain and vomiting. Two to three days later the virus produces a characteristic rash with bumps full of a clear liquid, which later fill with pus and finally develop a crust that dries and falls off. The rash begins on the face and hands, then spreads to the rest of the body. Lesions develop in the mucous membranes of the nose and mouth and ulcerate soon after formation (WHO, no date a).

The World Health Organization (WHO) has published guidance on case classification and surveillance standards (WHO, no date a).

Metrics and numeric limits

Not applicable.

Key relevant UN convention / multilateral treaty

Convention on the prohibition of the development, production and stockpiling of bacteriological (biological) and toxin weapons and on their destruction: Article I (UNODA, 1972).

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Vaccination campaigns and surveillance and prevention measures were undertaken to contain epidemic hotspots and to better inform affected populations. Smallpox was officially declared eradicated in 1980 and is the first disease to have been fought on a global scale (WHO, 2010).

Impacts: Smallpox was fatal in up to 30% of cases (WHO, 2010). Even a single confirmed case of smallpox today would be considered an emergency (CDC, 2024).

Multi-hazard Context: Thanks to a successful worldwide vaccination effort in the 20th century, smallpox has been eradicated. No smallpox case has been identified since 1977. Even a single confirmed case of smallpox today would be considered an emergency (CDC, 2024a; 2024b).

However, it is possible that variola virus could be used in a biological attack (an intentional release of viruses, bacteria, or other germs that can sicken or kill people, livestock, or crops). Public health authorities prepare for a possible but unlikely biological attack that uses smallpox as a weapon. Public health authorities are concerned about smallpox because it is a serious—even deadly—disease. Today, there are only two labs in the world that are approved to have the smallpox virus for research: the Centers for Disease Control and Prevention (CDC) in the United States and the Russian State Centre for Research on Virology and Biotechnology in the Russian Federation. There is credible concern that in the past some countries made the virus into weapons, which may have fallen into the hands of terrorists or other people with criminal intentions (CDC, no date). Post-eradication, there are concerns about accidental or deliberate release or reconstruction of variola virus that could be deployed as a biological weapon (UNODA, 1972).

Monitoring: WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date b).

Risk Management: Vaccination against smallpox can be used very effectively to prevent infection and disease (WHO, no date a). A global smallpox vaccine stockpile is maintained by the WHO to complement stocks held by a number of countries (WHO, 2017).

Preparedness for smallpox also entails education of health personnel in the differential diagnosis of smallpox, strengthening laboratory capacities for diagnostics, expansion of expertise in the area of laboratory biosafety and biosecurity, and strengthening of national-level biosafety regulations in all countries (WHO, no date a).

The WHO Smallpox Secretariat based in WHO Headquarters coordinates all smallpox eradication-related and post-eradication activities. These include overseeing permitted research with live variola virus for the development of countermeasures such as vaccines and antivirals. Since the eradication era, safer vaccines and specific treatments have been developed for smallpox and related diseases such as Mpox. The Secretariat is also responsible for emergency preparedness and manages a smallpox vaccine emergency stockpile in the unlikely event that the disease re-emerges. The Secretariat manages the biosafety and biosecurity measures of the authorized variola virus repositories as mandated by the World Health Assembly and ensures annual reporting to WHO Governing Bodies. The Smallpox Secretariat supports WHO Archives in preserving the global history of smallpox and documenting the lessons learned from the successful eradication of smallpox (WHO, no date a).

Preliminary – Corrections Pending

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Coordinating agency or organisation

World Health Organisation.

Preliminary – Corrections Pending

BI0236 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Severe Acute Respiratory Syndrome (SARS) (Human)

Definition

Severe acute respiratory syndrome (SARS) is a viral respiratory illness caused by a coronavirus called SARS-associated coronavirus (SARS-CoV). Among individuals who meet the current WHO case definition for confirmed SARS, the case-fatality rate is approximately 9.6% (WHO, no date).

Reference

WHO, no date. Severe Acute Respiratory Syndrome World Health Organization (WHO). https://www.who.int/health-topics/severe-acute-respiratory-syndrome#tab=tab_1 Accessed 27 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

SARS-CoV. SARS.

Additional scientific description

Severe acute respiratory syndrome (SARS) was first identified at the end of February 2003 during an outbreak that emerged in China and spread to four other countries (WHO, no date). The World Health Organization (WHO) coordinated the international investigation and worked closely with health authorities in affected countries to provide epidemiological, clinical and logistical support and to bring the outbreak under control (WHO, no date).

Most patients identified with SARS were previously healthy adults aged 25 to 70 years. A few suspected cases of SARS have been reported among children under 15 years of age (WHO, no date).

SARS is spread by close person-to-person contact. The virus that causes SARS is thought to be transmitted most readily by respiratory droplets (droplet spread) produced when an infected person coughs or sneezes. The virus can also spread when a person touches a surface or object contaminated with infectious droplets and then touches his or her mouth, nose, or eye(s). In addition, it is possible that the SARS virus might spread more broadly through the air (airborne spread) or by other ways that are not now known. The incubation period of SARS is usually 2 to 7 days but may be as long as 10 days (WHO, 2003b; no date).

SARS usually begins with a prodrome of fever (>38°C), which is often high, sometimes associated with chills and rigors and sometimes accompanied by other symptoms including headache, malaise, and myalgias. At the onset of illness, some cases have mild respiratory symptoms (WHO, no date).

The lower respiratory phase begins after 3 to 4 days with the onset of a dry, non-productive cough or dyspnea that may be accompanied by or progress to hypoxemia. In 10% to 20% of cases, the respiratory illness is severe enough to require intubation and mechanical ventilation (WHO, 2020). There is no cure or vaccine for SARS and treatment should be supportive and based on the patient's symptoms (WHO, no date).

Laboratory diagnosis is key to determining the aetiology of the symptoms including differential diagnosis with other coronaviruses including SARS-CoV-2. Early clinical recognition of SARS-CoV disease still relies on a combination of clinical, laboratory and epidemiologic features. No specific clinical findings can distinguish with certainty SARS-CoV disease from other respiratory illnesses rapidly (CDC, 2005).

No vaccine or specific treatment is available for SARS but it is part of the priority list for the WHO Research and Development Blueprint for Action to Prevent Epidemics (WHO, 2016a).

The WHO has published guidance on case classification and surveillance standards and recommendations on SARS and blood safety (WHO, 2003a; 2021).

Bats are highly likely to be the natural host of the virus responsible for SARS (CSIRO, 2021).

Metrics and numeric limits

The case fatality among persons with illness meeting the current WHO case definition for confirmed cases of SARS is around 9.6%. (WHO, no date).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016b).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: SARS-CoV-1 is a transmissible new disease to emerge in the 21st century and spread along respiratory routes, causing an epidemic through international air travel of people to other countries outside of their originating country (WHO, no date).

SARS can also be transmitted indirectly through the deposition of the virus onto surfaces via contaminated surfaces that have been touched by someone who is infected with the virus (WHO, no date).

Impacts: The case fatality among persons with illness meeting the current WHO case definition for probable and suspected cases of SARS is around 3% (WHO, no date).

Severe acute respiratory syndrome (SARS) is a viral respiratory disease caused by a SARS-coronavirus. While SARS cases were detected as early as November 2002 as part of an outbreak that emerged in China and subsequently spread to 28 other countries, the pathogen causing the disease was identified as a coronavirus at the end of February 2003 (WHO, no date).

An epidemic of (WHO, no date) severe acute respiratory syndrome (SARS) has been associated with an outbreak of atypical pneumonia originating in Guangdong Province, People's Republic of China. We aimed to identify the causative agent in the Guangdong outbreak and describe the emergence and spread of the disease within the province. SARS had been circulating in other cities of Guangdong Province for about 2 months before causing a major outbreak in Guangzhou, the province's capital. A novel coronavirus, SARS coronavirus (CoV), was isolated from specimens from three patients with SARS. Viral antigens were also directly detected in nasopharyngeal aspirates from these patients. 48 of 55 (87%) patients had antibodies to SARS CoV in their convalescent sera. Genetic analysis showed that the SARS CoV isolates from Guangzhou shared the same origin with those in other countries and had a phylogenetic pathway that matched the spread of SARS to other parts of the world (Li et al., 2003).

SARS was the first severe and readily transmissible new disease to emerge in the 21st century and spread along respiratory routes, causing an epidemic through international air travel of people to other countries outside of their originating country. SARS can also be transmitted indirectly through deposition of the virus onto surfaces via contaminated surfaces that have been touched by someone who is infected with the virus. Most patients who contracted SARS were previously healthy adults aged 25-70 years. A few suspected cases of SARS have been reported among children under 15 years. The case fatality among persons with illness meeting the current WHO case definition for confirmed cases of SARS is around 9.6%. (WHO, no date).

Multi-hazard Context: Not Applicable.

Monitoring: The Global Outbreak Alert and Response Network (GOARN) was established in April 2000 as a mechanism to aid technical partners and networks around the world to coordinate and provide targeted assistance and support to national health authorities, at their request, during public health emergencies. The GOARN weekly operations call serves as a platform for the Network's partners to connect regularly and share alerts and operational information so that all are informed about novel epidemic intelligence and partners' operations. First instituted in January 2017, the goal of the weekly call is to increase information-sharing among partners, increase collaboration and coordination, and ultimately improve emergency responses at the national, regional and global levels (WHO, 2024).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a disaster from natural hazards. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023).

Risk Management: Prevention mainly is through infection control in healthcare, home and community settings. Personal preventive measures to prevent the spread of the virus include frequent hand washing using soap or alcohol-based disinfectants. For those with a high risk of contracting the disease, such as healthcare workers, the use of personal protective equipment, including a mask, goggles and an apron is mandatory. Whenever possible, household contacts should also wear a mask (WHO, no date).

Preliminary – Corrections Pending

Control of SARS relies on the rapid identification of cases and their appropriate management, including the isolation of suspect and probable cases and the management of their close contacts (WHO, no date). Individuals under investigation should be placed in respiratory isolation and precautions strictly followed (WHO, no date).

Controlling outbreaks relies on containment measures (WHO, no date) including:

- prompt detection of cases through good surveillance networks and including an early warning system;
- isolation of suspected or probable cases;
- tracing to identify both the source of the infection and contacts of those who are sick and may be at risk of contracting the virus;
- quarantine of suspected contacts for 10 days;
- exit screening for outgoing passengers from areas with recent local transmission by asking questions and temperature measurement; and
- disinfection of aircraft and cruise vessels having SARS cases on board using WHO guidelines.

Personal preventive measures to prevent the spread of the virus include frequent hand washing using soap or alcohol-based disinfectants. For those with a high risk of contracting the disease, such as health-care workers, use of personal protective equipment, including a mask, goggles and an apron is mandatory. Whenever possible, household contacts should also wear a mask (WHO, no date).

To further reduce the risk that travellers may carry the SARS virus to new areas, international travellers departing from areas with local transmission should be screened for possible SARS at the point of departure (WHO, no date).

Controlling outbreaks relies on containment measures including: prompt detection of cases through good surveillance networks and an early warning system; isolation of suspected or probable cases; tracing to identify both the source of the infection and contacts of those who are sick and may be at risk of contracting the virus; quarantine of suspected contacts for 10 days; exit screening for outgoing passengers from areas with recent local transmission by asking questions and temperature measurement; and disinfection of aircraft and cruise vessels having SARS cases on board using WHO guidelines (WHO, no date).

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Preliminary – Corrections Pending

topics/severe-acute-respiratory-syndrome#tab=tab_1 Accessed 27 May 2025.

Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0237 / BIOLOGICAL / Infectious Diseases (Human and Animal)

zoonosis

Tuberculosis (Human and Animal)

Definition

Tuberculosis (TB) is a curable bacterial infectious disease caused by *Mycobacterium tuberculosis* that most commonly affects the lungs. It causes national epidemics of varied severity worldwide. Forms of TB that are resistant to treatment – multi-drug-resistant TB (MDR-TB) and extensively drug-resistant TB (XDR-TB) – are public health crises and threaten health security worldwide (WHO, 2024).

Reference

WHO, 2024. Tuberculosis. World Health Organization (WHO). www.who.int/news-room/fact-sheets/detail/tuberculosis Accessed 4 November 2024.

Preliminary – Corrections Pending

Annotations

Synonyms

Drug-resistant tuberculosis (DR-TB), Multidrug-resistant tuberculosis (MDR-TB), Extensively drug-resistant TB (XDR-TB), Rifampicin-resistant (RR-TB).

Additional scientific description

Human

Tuberculosis (TB) is caused by bacteria (Mycobacterium tuberculosis) that most often affect the lungs. TB is curable and preventable. It is spread from person to person through the air. When people with lung TB cough, sneeze or spit, they propel the TB germs into the air. A person needs to inhale only a few of these germs to become infected (WHO, 2024a).

About 5–10% of people infected with TB will eventually get symptoms and develop TB disease. Those who are infected but free of disease cannot transmit it. Following infection, the risk of developing TB disease is highest in the first 2 years (approximately 5%), after which it is much lower. TB disease is usually treated with antibiotics and can be fatal without treatment. In certain countries, the Bacille Calmette-Guérin (BCG) vaccine is given to babies or small children to prevent TB. The vaccine prevents deaths from TB and protects children from serious forms of TB. There is currently no licenced vaccine that is effective in preventing TB disease in adults, either before or after exposure to TB infection (WHO, 2024a)

The symptoms people get depend on which part of the body is affected by TB. While TB usually affects the lungs, it can also involve the kidneys, brain, spine and skin. The common symptoms of TB are coughing (sometimes with sputum or blood), chest pains, weakness, weight loss, fever, and night sweats. When a person develops TB, the symptoms may be mild for many months. This can lead to delays in seeking care, and results in transmission of the bacteria to others (WHO, 2024a).

Diagnostic tests for tuberculosis disease include sputum smear microscopy, rapid molecular tests and culture-based methods. WHO recommends the use of rapid molecular diagnostic tests as the initial diagnostic test in all persons with signs and symptoms of TB. Rapid diagnostic tests recommended by WHO include the Xpert MTB/RIF Ultra and Truenat assays. These tests have high diagnostic accuracy and will lead to major improvements in the early detection of TB and drug-resistant TB. A tuberculin skin test (TST), interferon gamma release assay (IGRA) or newer antigen-based skin tests (TBST) can be used to identify people with infection. TB is particularly difficult to diagnose in children (WHO, 2024a).

Multidrug-resistant tuberculosis (MDR-TB) is a form of drug-resistant TB caused by bacteria that do not respond to the two most powerful first-line anti-TB drugs — rifampicin and isoniazid. MDR-TB is treatable and curable by using second-line treatment options, which are limited and require extensive chemotherapy with medicines that are expensive and toxic. Extensively drug-resistant TB (XDR-TB) is a more serious form of MDR-TB caused by bacteria that do not respond to the most effective second-line anti-TB drugs, often leaving patients without any further treatment options (WHO, 2024a).

In 2024, MDR-TB remains a public health crisis and a health security threat. Globally in 2023, 175 923 people were diagnosed and treated for multidrug-resistant or rifampicin-resistant TB (MDR/RR-TB); this was 44% of the 400 000 people (95% UI: 360 000–440 000) estimated to have developed MDR/RR-TB in 2023. (WHO, 2024b).

The WHO has published information about case definitions and classification as well as consolidated guidelines for preventive treatment, systematic screening, rapid diagnostics, drug-resistant tuberculosis treatment, surveillance of drug resistance in tuberculosis and management of tuberculosis in children and adolescents (WHO, 2015; 2020; 2021a; 2021b; 2021c; 2024c).

Animal

Mammalian tuberculosis is a chronic bacterial disease of animals, and is also a major zoonotic disease, with cattle being the main source of infection for humans. *M. bovis* is estimated to account for up to 10% of human tuberculosis cases in some countries. Despite its impact, vaccination is not used as a preventive measure in animals, due to the lack of availability of safe and effective vaccines, and potential interference with mammalian tuberculosis surveillance and diagnostic tests, due to false positive reactions in vaccinated animals (WOAH, no date).

Mammalian tuberculosis is a chronic bacterial disease of animals caused by members of the Mycobacterium tuberculosis complex (MTBC). Within the complex, important variants include *M. bovis, M. caprae* and *M. tuberculosis*. Pathogens associated with domesticated and wild animals include *M. bovis, M. caprae, M. microti, M. orygis and M. pinnipedii*. It affects cattle, sheep, goats, equines, pigs, dogs and cats, and wildlife species such as wild boars, deer, and antelopes. The usual clinical signs include weakness, loss of appetite and weight, fluctuating fever, dyspnoea and intermittent hacking cough, signs of low-grade pneumonia, diarrhoea-enlarged and prominent lymph nodes (WOAH, no date).

Zoonotic TB is a less common form of human TB that is caused by a related member of the MTBC (*M. bovis*). The zoonotic form is primarily transmitted indirectly, through the consumption of contaminated milk, dairy products, or meat containing infected material. In regions where food hygiene is consistently applied, the risk to the general public has been reduced, however, zoonotic tuberculosis infection remains an occupational hazard for farmers, abattoir workers and butchers, which can impact their health and disrupt meat supply chains (WOAH, no date). *M. bovis* is naturally resistant to pyrazinamide, one of the four essential medications used in the current standard first-line anti-TB treatment regimen in humans (WHO, FAO & OIE, 2017).

Metrics and numeric limits

According to WHO (2024 a):

- TB occurs in every part of the world. TB has probably returned to being the world's leading cause of death from a single infectious agent, following three years in which it was replaced by coronavirus disease (COVID-19)
- A total of 1.25 million people died from tuberculosis (TB) in 2023 (including 161 000 people with HIV).
- In 2023, an estimated 10.8 million people fell ill with TB worldwide, including 6.0 million men, 3.6 million women and 1.3 million children. TB is present in all countries and age groups. TB is curable and preventable.
- Child and adolescent TB is often overlooked by health providers and can be difficult to diagnose and treat.
- Around 87% of new TB cases occurred in the 30 high TB burden countries, with more than two-thirds of the global total in Bangladesh, China, The Democratic Republic of Congo, India, Indonesia, Nigeria, Pakistan and the Philippines.
- Globally, the net reduction in the TB incidence rate between 2015 and 2023 was 8.3%, far from the WHO End TB Strategy milestone of a 50% reduction by 2025.

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard drivers and impacts:

Human

Hazard Drivers: About one-quarter of the world's population has latent tuberculosis infection (LTBI), which means people have been infected by TB bacteria but are not (yet) ill with the disease and cannot transmit the disease. Persons with compromised immune systems, such as people living with human immunodeficiency virus (HIV), malnutrition or diabetes, are at higher risk. People living with HIV are 16 (uncertainty interval 14–18) times more likely to fall ill with TB disease than people without HIV. TB is the leading cause of death among people with HIV (WHO, 2024). Risk factors for MDR-TB and XDR-TB include low adherence of patients to treatment, due to length and toxicity of regimen; poor quality or unavailable anti-TB drugs; and incorrect prescription of anti-TB medicines by health-care providers (WHO, 2019).

Impacts: Globally, about 50% of people treated for TB and their households face total costs (direct medical expenditures, non-medical expenditures and indirect costs such as income losses) that are catastrophic (>20% of total household income), far from the WHO End TB Strategy target of zero. Those with compromised immune systems, such as people living with HIV, undernutrition or diabetes, or people who use tobacco, have a higher risk of falling ill. Globally in 2023, there were estimated 0.96 million new TB cases that were attributable to undernutrition, 0.75 million to alcohol use disorders, 0.70 million to smoking, 0.61 million to HIV infection, and 0.38 million to diabetes (WHO, 2024a).

Animal

Hazard Drivers: Direct contact with an infected animal

Impacts: Zoonotic TB infection in humans

Preliminary – Corrections Pending

Multi-hazard Context: Severe weather events, like floods and extreme temperatures, can indirectly increase the risk of tuberculosis (TB) transmission and worsen existing TB cases. This happens by disrupting health-care access, causing displacement and overcrowding, and leading to malnutrition, which weakens the immune system and makes individuals more vulnerable to TB infection.

Climate change has a significant impact on tuberculosis through temperature-related factors. These factors influence the prevalence of, spread of, and vulnerability to TB. Addressing these challenges requires a holistic approach involving adaptation planning (Tosepu et al., 2024).

The impact of armed conflicts on tuberculosis notification is complex and is influenced by multiple factors. The findings of this review underscore the importance of concerted efforts to control tuberculosis in conflict settings (Gebreyohannes et al, 2024)

Nyasulu et al. (2025) report that TB among prisoners accounts for approximately 1% of the global incidence of TB and that TB treatment is associated with lower treatment success rates among prisoners. They consider that TB in prisons and detention centres constitutes a considerable public health challenge.

Monitoring: The WHO Global Tuberculosis Report and WHO's online global TB database provide a comprehensive and up-to-date assessment of the TB epidemic and of progress in prevention, diagnosis and treatment of the disease, at global, regional and country levels. This is done in the context of global TB commitments, strategies and targets. The report is based primarily on data gathered by WHO from national ministries of health in annual rounds of data collection. In 2024, 193 countries and areas with more than 99% of the world's population and TB cases reported data (WHO, 2024 b).

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country's risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARSs should re-integrate back into the national system (WHO, no date, a).

Human
Risk Management: The main health care intervention available to reduce the risk of TB infection progressing to active TB disease is TB preventive treatment. Other preventive interventions are TB infection prevention and control, and vaccination of children with the bacille Calmette-Guérin (BCG) vaccine, which can confer protection, especially from severe forms of TB in children. WHO recommends TB preventive treatment for people living with HIV, household contacts of people diagnosed with bacteriologically confirmed pulmonary TB and clinical risk groups (e.g. those receiving dialysis) (WHO, 2024 b). The main challenges in the treatment of TB disease are the duration and complexity of drug regimens, both of which affect adherence; adverse drug reactions, especially for the drugs used to treat drug-resistant TB; and the absence or limited availability of paediatric drug formulations for second-line treatment (WHO, 2020). TB treatment for people co-infected with HIV is further complicated by drug-drug interactions between anti-TB drugs and antiretroviral therapies and by cumulative drug toxicities (WHO, 2019). There is a pressing need for anti-TB regimens that are more effective, more affordable and nontoxic, and that shorten the duration of treatment (WHO, 2020). Ending TB is not just a public health problem, but a development challenge and opportunity. WHO's post-2015 End TB Strategy, adopted by the World Health Assembly in 2014, aims to end the global TB epidemic as part of the newly adopted Sustainable Development Goals. It serves as a blueprint for countries to reduce TB incidence by 80%, and TB deaths by 90%, and to eliminate catastrophic costs for TB-affected households by 2030. The Strategy is not a "one size fits all" approach and its success depends on adaptation to diverse country settings. (WHO, no date b).
Animal
Risk Management: Biosecurity, reducing inter/intra-herd and wildlife0livestock transmission, raising awareness

Preliminary – Corrections Pending

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Coordinating agency or organisation

World Health Organization.

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BI0238 / BIOLOGICAL / Infectious Diseases (Human and Animal)

zoonosis

Trypanosomiasis

Definition

Trypanosomiasis, human African (sleeping sickness) and animal trypanosomosis (nagana) are caused by protozoan parasites belonging to the genus *Trypanosoma* transmitted by infected tsetse flies and is endemic in sub-Saharan Africa. Without treatment, the disease is considered fatal (adapted from WHO, 2023 and FAO, no date).

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Annotations

Synonyms

Sleeping sickness.

Additional scientific description

Human

Human African trypanosomiasis, also known as sleeping sickness, is a vector-borne parasitic disease. It is caused by infection with protozoan parasites belonging to the genus Trypanosoma. They are transmitted to humans by tsetse fly (Glossina genus) bites which have acquired their infection from humans or from animals harbouring human pathogenic parasites (WHO, 2023).

Tsetse flies are only found in sub-Saharan Africa and only certain species transmit the disease. Rural populations in regions where transmission occurs and which depend on agriculture, fishing, animal husbandry or hunting are the most exposed to the tsetse fly and thus to the disease. The disease develops in areas ranging from a single village to an entire region. Within an infected area, the intensity of the disease can vary from one village to the next (WHO, 2023).

Human African trypanosomiasis takes two forms, depending on the parasite involved:

- *T. brucei gambiense* is found in 24 countries in west and central Africa. This form currently accounts for 92% of reported cases of sleeping sickness and causes infection (WHO, 2023).
- *T. brucei rhodesiense* is found in 13 countries in eastern and southern Africa. This form accounts for 8% of reported cases and causes an acute disease. The disease develops rapidly and invades the central nervous system. Only Uganda presents both forms of the disease, but in separate zones (WHO, 2023).

Another form of trypanosomiasis occurs mainly in Latin America. It is known as American trypanosomiasis or Chagas disease. The causal organism belongs to a different Trypanosoma subgenus and is transmitted by a different vector (WHO, 2023).

Major human epidemics have occurred in Africa over the past century: one between 1896 and 1906, mostly in

Uganda and the Congo Basin; one in 1920 in a number of African countries; and the most recent epidemic started in 1970 and lasted until the late 1990s (WHO, 2023).

The 1920 epidemic was controlled by mobile teams which carried out the screening of millions of people at risk. By the mid-1960s, the disease was under control with less than 5000 cases reported in the whole continent. After this success,

surveillance was relaxed, and the disease reappeared, reaching epidemic proportions in several regions by 1970. The efforts of the World Health Organization (WHO), national control programmes, bilateral cooperation and non-governmental organisations (NGOs) during the 1990s and early 21st century reversed the curve (WHO, 2023).

Currently, the disease incidence differs from one country to another as well as in different parts of a single country. In the past 5 years, over 61% of reported cases occurred in the Democratic Republic of the Congo (WHO, 2023).

Angola, Central African Republic, Chad, Congo, Gabon, Guinea, Malawi and South Sudan declared between 10 and 100 new cases in the last 5 years. Cameroon, Côte d'Ivoire, Equatorial Guinea, Kenya, Uganda, United Republic of Tanzania, Ethiopia and Zambia declared between 1 and 10 new cases in the last 5 years. Burkina Faso, Ghana, Kenya, Nigeria and Zimbabwe have reported sporadic cases in the last decade. Benin, Botswana, Burundi, Eswatini, Gambia, Guinea Bissau, Liberia, Mali, Mozambique, Namibia, Niger, Rwanda, Senegal, Sierra Leone and Togo have not reported any new cases for over a decade. Transmission of the disease seems to have stopped in some of these countries but there are still some areas where it is difficult to assess the exact situation because the unstable social circumstances and/or difficult accessibility hinder surveillance and diagnostic activities (WHO, 2023).

Animal

Tsetse-transmitted animal trypanosomosis occurs in tropical regions of sub-Saharan Africa, where it constitutes a major obstacle to the development of animal production. The considerable economic and social repercussions make control of this disease a priority for the development of a large part of the African continent.

There are no effective vaccines commercially available against Trypanosomes.

- African animal trypanosomosis affects ruminants, swine, camels, equines, and carnivores, as well as a broad range of wild animals, but the heaviest economic burden is in cattle. In cattle, the disease is called Nagana.
- The disease is caused by several species of trypanosome but mainly by *Trypanosoma congolense*, *T. vivax, T. brucei*, and *T. simiae. T. vivax* is also present in Latin America, where in the absence of tsetse flies it is transmitted by other biting flies.
- A different species (i.e. *T. evansi*) is also present outside of Africa, including Asia.
- Trypanosomes have developed refined mechanisms to escape from the immune system by either changing their own "antigen appearance" and/or actively eliminating the B cell memory compartment (Marcelino, I. et al, 2021).
- Control and, where feasible, elimination of animal trypanosomosis as a disease with a zoonotic dimension would help to improve animal production in Africa considerably and would also contribute to enhancing human health (Diall et al., 2017).
- Transmission of trypanosomes by insects occurs through cyclical transmission or mechanical transmission.
- Cyclical transmission, during which the trypanosomes actively multiply in the vectors, occurs in sub-Saharan Africa through the intermediary of tsetse flies (*Glossina spp*.) (Cecchi et al., 2024). Mechanical transmission can be caused by various blood-sucking insects such as flies of the family *Tabanidae* (horse flies) and *Stomoxys spp.* (Diall et al., 2017).
- Animals can host the human pathogen parasites, especially *T. brucei rhodesiense*, of which domestic and wild animals are the most important reservoirs. Animals can also be infected with *T. brucei gambiense* and possibly act as a reservoir to some extent. However, the precise epidemiological role of the animal reservoir in the gambiense form of the disease is not yet well known (WHO, 2023).
- Trypanosomosis (tsetse-transmitted) is one of the World Organisation for Animal Health (WOAH) Listed diseases (WOAH, 2024)

Preliminary – Corrections Pending

Metrics and numeric limits

In 1998, almost 40,000 cases of trypanosomiasis were reported, but estimates were that 300,000 cases were undiagnosed and therefore untreated. During the last epidemic, the prevalence reached 50% in several villages in Angola, the Democratic Republic of Congo, and South Sudan. Sleeping sickness was the first or second greatest cause of mortality in those communities. After continued control efforts, HAT occurrence reached a historic low under 2,000 cases in 2017 and under 1,000 cases in 2018, remaining below that threshold as of 2022. The population at risk estimated for the period 2016-2020 was 55 million people, with only 3 million at moderate-high risk (WHO, 2023).

Key relevant UN convention / multilateral treaty

WHO. 2013. International Health Regulations (2005), 3rd ed. (WHO, 2016).

WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) (WTO, 1994).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers and Impacts

Human
Hazard Drivers: The disease is mostly transmitted through the bite of an infected tsetse fly but there are other ways in which people are infected. These include mother-to-child infection (the trypanosome can cross the placenta and infect the foetus); mechanical transmission through other blood-sucking insects, however, it is difficult to assess its epidemiological impact; accidental infections in laboratories due to pricks with contaminated needles; and transmission of the parasite through sexual contact has been reported once (WHO, 2023). **Impacts**: Sleeping sickness threatens millions of people in 36 countries in sub-Saharan Africa. Many of the affected populations live in remote rural areas with limited access to adequate health services, which complicates the surveillance and therefore the diagnosis and treatment of cases. In addition, displacement of populations, war and poverty are important factors that facilitate transmission (WHO, 2023). Symptoms of the disease in the first stage start when the trypanosomes multiply in subcutaneous tissues, blood and lymph. This is also called the haemo-lymphatic stage, which entails bouts of fever, headaches, enlarged lymph nodes, joint pains and itching. In the second stage the parasites cross the blood-brain barrier to infect the central nervous system. This is knownas the neurological or meningo-encephalic stage. In general, this is when more obvious signs and symptoms of the disease appear: changes in behaviour, confusion, sensory disturbances and poor coordination. Disturbance of the sleep cycle, which gives the disease its name, is an important feature. Without treatment, sleeping sickness is considered fatal although rare cases of self-cure have been reported (WHO, 2023).
Animal
Hazard Drivers: presence/introduction of Trypanosoma infected tsetse fly. **Impacts**: mortality and morbidity of animals and humans, spread of infection.

Multi-hazard Context: Not Applicable

Monitoring: The table below offers an overview of monitoring for trypanosomiasis and trypanosomosis. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	WHO, Ministry of Health, FAO Reference Centres, WHO Collaborating Centres, WOAH Reference Centres,
How is the Hazard Observed/Monitored/Forecast?	FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021b).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARSs should re-integrate back into the national system (WHO, no date, a).

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Risk Management

Human
Risk Management: New WHO treatment guidelines for gambiense-HAT were issued in 2019 (WHO, 2023). The WHO neglected tropical diseases road map targeted its elimination as a public health problem by 2020 and interruption of transmission (zero cases) for 2030 (WHO, 2023). The WHO and its partners provide support and technical assistance to national control programmes and provide the anti-trypanosome medicines free of charge to endemic countries through public-private partnerships with Sanofi (pentamidine, melarsoprol, eflornithine, fexinidazole) and Bayer HealthCare (suramin, nifurtimox) (WHO, 2021 a). In 2008, the WHO launched the Atlas of human African Trypanosomiasis initiative to map at village-level all reported cases (WHO, no date b). This initiative is jointly implemented with the Food and Agriculture Organization of the United Nations (FAO) within the PAAT framework (FAO, 2021). The PAAT was officially established in November 1997 by the 29th Session of the FAO Conference (Resolution 5/97). The PAAT secretariat includes representatives of the Food and Agriculture Organization of the United Nations (FAO), the International Atomic Energy Agency (IAEA), the World Health Organization (WHO) and the African Union-Interafrican Bureau for Animal Resources (AU-IBAR) (FAO, 2025). Progressive Control Pathways (PCPs) and the related roadmaps are staged, stepwise approaches increasingly used to structure the road to disease reduction and freedom for a range of human and animal diseases, including foot-and-mouth disease (BI0306), peste des petits ruminants (BI0310), brucellosis (BI0202) and rabies (BI0232). The PCP for African Animal Trypanosomosis is developed and promoted by FAO within the framework of PAAT, and in collaboration with IAEA, AU-PATTEC and CIRAD. The Atlas is a dynamic database including geographical and epidemiological data, compiled by the WHO through the contribution of SSNCPs, NGOs and research institutes (WHO, no date b). In 2014, a coordination network for human African trypanosomiasis was established under WHO leadership to ensure strengthened and sustained efforts to eliminate the disease. The stakeholders include national sleeping sickness control programmes, groups developing new tools to fight the disease, international and NGOs, and donors (WHO, 2023). WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021b). WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023).
Animal
Risk Management: Disease control for animal trypanosomosis includes treatment with trypanocides, vector control and strengthened surveillance (Diall et al., 2017).

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Accessed 24 May 2025.

Coordinating agency or organisation

Food and Agriculture Organization of the United Nations (FAO), World Health Organization (WHO), World Organisation for Animal Health (WOAH).

Preliminary – Corrections Pending

BI0239 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Varicella and herpes zoster (Human)

Definition

Varicella is an acute, highly contagious disease caused by varicella-zoster virus. Following infection, the virus remains latent in neural ganglia and in about 10-20% of cases it is reactivated to cause herpes zoster, or shingles, generally in persons over 50 years of age or immunocompromised individuals. (WHO, no date).

Reference

WHO, no date. Varicella. World Health Organization (WHO). https://www.who.int/teams/health-product-policy-and-standards/standards-and-specifications/norms-and-standards/vaccine-standardization/varicella Accessed 27 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Chickenpox.

Additional scientific description

Varicella zoster virus (VZV) is a member of the herpesvirus family. Only one serotype of VZV is known, and humans are the only reservoir (WHO, no date).

Following infection, the virus remains latent in neural ganglia and in some cases, it is reactivated to cause herpes zoster, or shingles, generally in elderly or immunocompromised individuals (WHO, no date).

Initial infection with VZV causes varicella (or chickenpox). While mostly a mild disorder in childhood, varicella tends to be more severe in adults. It may be fatal, especially in neonates and in immunocompromised persons. Infection during early pregnancy can rarely lead to destructive lesions in the fetus with shingles-like scarring of tissues (Lamont et al., 2011).

Varicella is characterised by an itchy rash of small blisters, usually starting on the scalp and face and initially accompanied by fever and malaise. The rash gradually spreads to the trunk and limbs but tends to spare the hands and feet. The blisters gradually dry out and crusts appear which then disappear over a period of one to two weeks (WHO, no date).

The infection may occasionally be complicated by pneumonia or encephalitis (inflammation of the brain), at times with serious or fatal consequences (WHO, no date).

Shingles is a painful rash, usually affecting a zone on one side of the face or body, that may occasionally result in permanent damage to the nerves or cause visual impairment. In immunosuppressed individuals it is severe and often dangerous but can be treated with antiviral medicines (WHO, no date).

VZV transmission occurs via droplets, aerosols, or direct contact with respiratory secretions, and almost always produces clinical disease in susceptible individuals. Shingles is less infectious than chickenpox as the rash is limited and respiratory involvement is much less common (WHO, no date).

The World Health Organization (WHO) has published guidance on case classification and surveillance standards (WHO, no date).

Metrics and numeric limits

According to CDC (2024) varicella used to be very common in the United States and contributed significantly to the burden of childhood disease. In the early 1990s each year: More than 4 million people got varicella 10,500 to 13,500 were hospitalized 100 to 150 died. More than 90% of cases, 70% of hospitalizations, and about half of the deaths occurred in children (CDC, 2024).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Chickenpox is very contagious and spreads in several ways. It spreads through the air when an infected person coughs or sneezes, releasing droplets containing the virus. The virus can also spread through direct contact with the fluid from chickenpox blisters or respiratory secretions. A person is contagious from one to two days before the rash appears until all the blisters have formed scabs. This ease of transmission is why chickenpox can easily spread in places like schools and daycare centres. The secondary attack rate for chickenpox is high, with 61-100% of susceptible individuals contracting the disease after being exposed (WHO, 2025).

While chickenpox is usually a mild illness, it can lead to complications, particularly in certain groups of people. These complications can include pneumonia (lung infection), encephalitis (inflammation of the brain) and bacterial infections of the skin. These complications can be severe and sometimes fatal. Although severe complications are more likely in individuals with weakened immune systems, most deaths from chickenpox occur in otherwise healthy children because the disease is so common. Those at higher risk for severe complications include infants under one year of age, pregnant women, adults and people with compromised immune systems (WHO, 2025).

Impacts: Although varicella is usually self-limiting it may be associated with severe complications, mediated either by VZV or secondary bacterial infection. Extra-cutaneous complications affecting the central nervous system range from cerebellar ataxia to encephalitis (WHO, 2014).

The most common complications in children are secondary bacterial infections. VZV pneumonia frequently with secondary bacterial infection is the most common complication in adults. Groups at higher risk for severe complications are neonates, infants, pregnant women, older adults, and immunocompromised persons – including those who are taking oral corticosteroids (WHO, 2014).

Anyone who has had chickenpox can develop shingles. However, it's much more common in adults over the age of 50. The risk increases with age because the immune system tends to weaken, making it harder to keep the VZV suppressed. Other factors that can increase the risk of shingles include:

- ***Weakened immune system.*** Conditions like HIV and AIDS, cancer, and organ transplantation, as well as medications that suppress the immune system, can increase the risk.
- ***Stress.*** Periods of high stress may temporarily weaken the immune system, potentially triggering a shingles outbreak.
- ***Certain medical conditions.*** Conditions like diabetes, chronic kidney disease and lung disease may increase the risk (WHO, 2025).

While chickenpox is usually a mild illness, it can lead to complications, particularly in certain groups of people. These complications can include pneumonia (lung infection), encephalitis (inflammation of the brain) and bacterial infections of the skin. These complications can be severe and sometimes fatal. Although severe complications are more likely in individuals with weakened immune systems, most deaths from chickenpox occur in otherwise healthy children because the disease is so common. Those at higher risk for severe complications include infants under one year of age, pregnant women, adults and people with compromised immune systems (WHO, 2025).

Multi-hazard Context: Not Applicable.

Monitoring: WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a disaster from natural hazards. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023).

Risk Management: Supportive measures include relief of chickenpox symptoms, prevention of skin infections and prompt treatment for pneumonia which often needs both antivirals and antibiotics as staphylococcal superinfection is very common. Intake of fever medications may help symptoms, but caution must be observed in children (WHO, 2014).

Vaccines against both varicella and HZ are based on live attenuated VZV (Oka strain); they differ in the number of plaque-forming viral units per vaccine dose and volume of the inoculum. (WHO, 2014).

Chickenpox is a preventable disease. There are also several steps that can be taken to reduce the spread of the disease. These

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include avoiding contact with infected individuals, avoiding sharing personal items like towels and utensils, and practicing good hygiene. People with chickenpox should avoid leaving home until all their lesions have crusted and dried. Those with modified varicella (breakthrough cases) should isolate themselves until no new lesions appear for 24 hours (WHO, 2025).

WHO recommends that the use of the recombinant herpes zoster vaccine in a 2-dose schedule with a minimum 2-month interval between doses, for the prevention of herpes zoster in older adults and those with chronic conditions, be considered in countries where herpes zoster is an important public health problem. WHO advised countries to conduct cost-effectiveness analyses to inform decision-making (WHO, 2025).

Severe or complicated cases including susceptible pregnant women can be treated with appropriate antiviral medicines (WHO, 2014).

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0240 / BIOLOGICAL / Infectious Diseases (Human and Animal)

zoonosis

West Nile Fever (Human and Animal)

Definition

West Nile virus disease is a potentially fatal neurological disease caused by a virus transmitted through the bites of infected mosquitoes. The virus is a member of the *flavivirus* genus and belongs to the Japanese encephalitis antigenic complex of the family *Flaviviridae* (WHO, 2017).

Reference

WHO, 2017. West Nile virus. World Health Organization (WHO). www.who.int/news-room/fact-sheets/detail/west-nile-virus Accessed 30 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

West Nile Disease. WNV.

Additional scientific description

Human
West Nile virus disease can cause neurological disease and death in people. West Nile virus (WNV) is commonly found in Africa, Europe, the Middle East, North America and West Asia. WNV is maintained in nature in a cycle involving transmission between birds and mosquitoes. Humans, horses and other mammals can be infected (WHO, 2017). WNV was first isolated in a woman in the West Nile district of Uganda in 1937. It was identified in birds (crows and columbiformes) in the Nile Delta region in 1953. Before 1997, WNV was not considered pathogenic for birds, but at that time, in Israel a more virulent strain caused the death of different bird species presenting signs of encephalitis and paralysis. Human infections attributable to WNV have been reported in many countries for over 50 years. In 1999, a WNV circulating in Israel and Tunisia was imported into New York producing a large and dramatic outbreak that spread throughout the continental USA in the following years. The WNV outbreak in the USA (1999–2010) highlighted that the importation and establishment of vector-borne pathogens outside their current habitat represent a serious danger to the world. The largest outbreaks occurred in Greece, Israel, Romania, Russia and the USA. Outbreak sites are on major bird migratory routes. In its original range, WNV was prevalent throughout Africa, parts of Europe, the Middle East, West Asia, and Australia. Since its introduction in 1999 into the USA, the virus has spread and is now widely established from Canada to Venezuela (WHO, 2017). West Nile Virus is maintained in nature in a mosquito-bird-mosquito transmission cycle. Mosquitoes of the genus Culex are generally considered the principal vectors of WNV, in particular *C. pipiens*. WNV is maintained in mosquito populations through vertical transmission (adults to eggs). Birds are the reservoir hosts of WNV. In Europe, Africa, the Middle East and Asia, mortality in birds associated with WNV infection is rare. In striking contrast, the virus is highly pathogenic for birds in the Americas. Members of the crow family (Corvidae) are particularly susceptible, but the virus has also been detected in dead and dying birds of more than 250 species. Birds can be infected through a variety of routes other than mosquito bites, and different species may have different potential for maintaining the transmission cycle. Horses, just like humans, are 'dead-end' hosts, meaning that while they become infected, they do not spread the infection. Symptomatic infections in horses are also rare and generally mild but can cause neurological disease, including fatal encephalomyelitis (WHO, 2017).
Animal
WNV has a broad host range. It replicates in birds, reptiles, amphibians, mammals, mosquitoes and ticks (WOAH, no date). Birds are the natural hosts of WNV and can be infected through various routes. The virus has been detected in more than 250 bird species. Mortality of birds due to WNV in the Americas is high, especially in crows, while rare in Europe, Africa, the Middle East and Asia (WHO, 2017). Mammals e.g. horses, can become infected from the bite of an infected mosquito but are considered dead-end hosts (ECDC, no date). In horses, clinical signs of the neurologic disease caused by WNV may include loss of appetite, depression, stumbling, muscle twitching, partial paralysis, impaired vision, head pressing, teeth grinding, aimless wandering, convulsions, circling, and an inability to swallow. Weakness, usually in the hind limbs, is sometimes followed by paralysis. Coma and death may occur. Fever has been seen in some but

not all cases. Vaccines for horses are available. In areas where the disease is common, vaccination of horses is considered to be an effective control measure (WOAH, no date).

Metrics and numeric limits

The Centers for Disease Control and Prevention and the European Commission have published guidance on case classification and surveillance standards (CDC, 2015; European Union, 2018).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers and Impacts

Human
Hazard Drivers: Human infection is most often the result of bites from infected mosquitoes. Mosquitoes become infected when they feed on infected birds, which circulate the virus in their blood for a few days. The virus eventually gets into the mosquito's salivary glands. During later blood meals (when mosquitoes bite), the virus may be injected into humans and animals, where it can multiply and possibly cause illness (WHO, 2017). People and animals can also become infected by coming into contact with other infected animals, their blood, or other tissues (WHO, 2024). WNV can also be transmitted through organ transplants, blood transfusions, during pregnancy delivery, and through breast milk, though this is rare. To date, no human-to-human transmission of WNV through everyday contact has been documented (WHO, 2024). A very small proportion of human infections have occurred through organ transplants, blood transfusions and breast milk. There is one reported case of transplacental (mother-to-child) WNV transmission. To date, no human-to-human transmission of WNV through casual contact has been documented, and no transmission of WNV to health-care workers has been reported when standard infection control precautions have been put in place. However, transmission of WNV to laboratory workers has been reported (WHO, 2017). **Impacts**: Infection with WNV is either asymptomatic (no symptoms) in around 80% of infected people or can lead to West Nile fever or severe West Nile disease. About 20% of people who become infected with the WNV will develop West Nile fever. The symptoms of severe disease (also called neuroinvasive disease, such as West Nile encephalitis or meningitis, or West Nile poliomyelitis) include headache, high fever, neck stiffness, stupor, disorientation, coma, tremors, convulsions, muscle weakness, and paralysis. It is estimated that approximately 1 in 150 persons infected with WNV will develop a more severe form of disease. Serious illness can occur in people of any age, however, people over the age of 50 years and some immunocompromised persons (for example, transplant patients) are at the highest risk for getting severely ill when infected with WNV. The incubation period is usually 3 to 14 days (WHO, 2017). Diagnosis is by laboratory tests, including molecular tests (PCR) which can detect the virus genome during the acute phase of infection, and by serological tests to detect the individual's immune response to recent or past infection (WHO, 2017)
Animal
Hazard Drivers: Infection in mosquito **Impacts**: WN viral encephalitis occurs in only a small percentage of infected horses; the majority of infected horses do not display clinical signs. The mortality rate is approximately one in three clinically affected unvaccinated horses (WOAH, 2024a).

Multi-hazard Context: Multiple factors can contribute to alterations in vector-host contact ratios, including mosquito feeding preferences and changes in habitat structures. For example, urbanisation, which is projected to increase the urban population to approximately two-thirds by 2050, has been shown to cause notable changes in the distribution and abundance of mosquito species at the local level, with implications for disease transmission dynamics of vector-borne diseases including WNV.

Monitoring: The table below offers an overview of monitoring for West Nile fever. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Ministry of Agriculture, Ministry of Livestock, Ministry of Health, FAO Reference Centres, WOAH Reference Centres, WHO
How is the Hazard	Through its global early warning system, FAO has been supporting Members with risk monitoring, assessment and forecasting for animal health threats to enhance preparedness and response to animal health threats: • The Global Animal Disease Information System, EMPRES-i+, plays a crucial role in supporting countries with early warning and early detection of animal disease outbreaks. By providing a comprehensive platform for real-time disease tracking, EMPRES-i+, enables monitoring and analysis of animal health threats effectively,

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Observed/Monitored/Forecast?	collaborating closely with countries and regions on disease information sharing. This supports the dissemination of risk assessments and alerts for evidence-based decision-making. • FAO develops and maintains decision support tools that provide risk maps of existing and predicted risks of animal disease emergence, as well as other threats to the agri-food chain. • Additionally, FAO collaborates closely with international organizations like WHO and WOAH to verify disease information through integrated mechanisms such as the Epidemic Intelligence from Open Sources (EIOS), the Global Early Warning System (GLEWS+), and the World Animal Health Information System (WAHIS) for WOAH-listed diseases. These collaborations allow for the dissemination of early warning alerts and risk assessments to Members, to enable timely responses to potential outbreaks. FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country's risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023).

Risk Management

Human
Risk Management: Preventing transmission in horses is important. Since WNV outbreaks in animals precede human cases, the establishment of an active animal health surveillance system to detect new cases in birds and horses is essential to provide early warning for veterinary and human public health authorities. In the Americas, it is important to help the community by reporting dead birds to local authorities (WHO, 2017). Vaccines have been developed for horses. Treatment is supportive and consistent with standard veterinary practices for animals infected with a viral agent (WHO, 2017). In the absence of a vaccine (although there are vaccine candidates for a human vaccine under development), the only way to reduce infection in people is by raising awareness of the risk factors and educating people about the measures they can take to reduce exposure to the virus. Public health educational messages should focus on the following (WHO, 2017): • Reducing the risk of mosquito transmission. Efforts to prevent transmission should first focus on personal and community protection against mosquito bites through the use of mosquito nets, personal insect repellent, by wearing light-coloured clothing (long-sleeved shirts and trousers), and by avoiding outdoor activity at peak biting times. • Reducing the risk of animal-to-human transmission. Gloves and other protective clothing should be worn while handling sick animals or their tissues and during slaughtering and culling procedures. • Reducing the risk of transmission through blood transfusion and organ transplant. Effective prevention of human WNV infections depends on the development of comprehensive, integrated mosquito surveillance and control programmes in areas where the virus occurs. Studies should identify local mosquito species that play a role in WNV transmission, including those that might serve as a 'bridge' from birds to human beings. Emphasis should be on integrated control measures including source reduction (with community participation), water management, chemicals, and biological control methods (WHO, 2017). Health-care workers caring for patients with suspected or confirmed WNV infection, or handling specimens from them, should implement standard infection control precautions (WHO, 2017). The World Health Organization (WHO) Regional Office for Europe and the WHO Regional Office for the Americas/Pan American Health Organization are intensively supporting WNV surveillance and outbreak response activities, respectively, in Europe and in North America, Latin America and the Caribbean, together with country offices and international partners (WHO, 2017).
Animal
Risk Management: vector control, vaccination (horses)

Preliminary – Corrections Pending

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0241 / BIOLOGICAL / Infectious Diseases (Human and Animal)

zoonosis

Yellow Fever (Human)

Definition

Yellow fever is an acute viral haemorrhagic disease transmitted by infected mosquitoes and is a high-impact high-threat disease, with risk of international spread, which represents a potential threat to global health security (WHO, 2023).

Reference

WHO, 2023. Yellow fever. World Health Organization (WHO). https://www.who.int/news-room/fact-sheets/detail/yellow-fever . Accessed 27 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Not found.

Additional scientific description

Yellow fever virus is an arbovirus of the flavivirus genus and is transmitted by mosquitoes, belonging to the *Aedes* and *Haemogogus* genus. The different mosquito species live in different habitats – some breed around houses (domestic), others in the jungle (wild), and some in both habitats (semi-domestic). There are three types of transmission cycles: sylvatic (or jungle) yellow fever; intermediate yellow fever; and urban yellow fever. The virus is endemic in tropical areas of Africa and Central and South America (WHO, 2023).

Human
Once contracted, the yellow fever virus incubates in the body for 3 to 6 days. Many people do not experience symptoms, but when these do occur, the most common are fever, muscle pain with prominent backache, headache, loss of appetite, and nausea or vomiting. Symptoms disappear after 3 to 4 days (WHO, 2023). A small proportion of patients may enter a more toxic phase within 24 hours of recovering from initial symptoms. High fever returns and usually the liver and the kidneys are affected. People in this phase are likely to develop jaundice (yellowing of the skin and eyes), dark urine and abdominal pain with vomiting. Bleeding can occur from the mouth, nose, eyes or stomach. Half of the patients in this toxic phase die within 7 to 10 days (WHO, 2023). Polymerase chain reaction (PCR) testing in blood and urine can sometimes detect the virus in the early stages of the disease. In later stages, testing to identify antibodies is needed (WHO, 2023). The World Health Organization (WHO) has published guidance on case classification and surveillance standards (WHO, 2015).
Animal
Mosquitoes acquire the virus by feeding on infected primates (human or non-human) and then can transmit the virus to other primates (human or non-human). The jungle (sylvatic) cycle involves transmission of the virus between non-human primates (e.g., monkeys) and mosquito species found in the forest canopy. The virus is transmitted by mosquitoes from monkeys to humans when humans are visiting or working in the jungle (CDC, 2024).

A list of countries[1] with a risk of yellow fever transmission[2] and countries requiring proof of vaccination against yellow fever are listed in the table below (WHO, 2022). This list includes only countries or areas where WHO has determined there is a risk of yellow fever transmission and/or where there are country requirements for travellers.

[1] For the purpose of this publication, the terms "country" and "countries" refer to countries, territories, and areas.

[2] Risk of yellow fever transmission is defined as yellow fever being currently reported, or having been reported in the past, and the presence of vectors and animal reservoirs representing a potential risk of infection and transmission

-	Country requiring proof of vaccination against yellow fever for travellers[4] arriving from:			
Country determined by WHO to be at risk for yellow fever transmission[2, 3]	**Countries determined by WHO to be at risk for yellow fever transmission[2] (traveller ≥ 9 month)**	**Countries determined by WHO to be at risk for yellow fever transmission[2] (traveller ≥ 1 year)**	**Any country (traveller ≥ 9 month)**	**Any country (traveller ≥ 1 year)**
Angola; Argentina (Misiones and Corrientes Provinces); Benin; Bolivia; Brazil; Burkina Faso; Burundi; Cameroon; Central African Republic; Chad; Colombia; Congo; Côte d'Ivoire; Democratic Republic of the Congo; Ecuador (including Galapagos Islands); Equatorial Guinea; Ethiopia; French Guiana; Gabon; Gambia; Ghana; Guinea; Guinea-Bissau; Guyana; Kenya; Liberia; Mali; Martinique; Mauritania; Niger; Nigeria; Panama; Paraguay; Peru; Senegal; Sierra Leone; South Sudan; Sudan; Suriname; Togo; Trinidad and Tobago; Uganda; Venezuela.	Algeria; Aruba; Bahrain; Bonaire; Brunei Darussalam; Chad; China; Colombia; Costa Rica; Cuba; Curaçao; Egypt; Equatorial Guinea; Eritrea; Eswatini; Ethiopia; Gambia; Guinea; India; Indonesia; Iran; Kazakhstan; Madagascar; Maldives; Malta; Namibia; Nepal; Niue; Oman; Philippines; Qatar; Saint Lucia; Saudi Arabia; Senegal; Sint Eustatius (≥6 months); Sint Maarten; Solomon Islands; Sri Lanka; Thailand; United Arab Emirates; Zimbabwe.	Albania; Antigua and Barbuda; Australia; Bahamas; Bolivia; Botswana; Cabo Verde; Cambodia; Christmas Island; Democratic People's Republic of Korea; Djibouti; Dominica; Dominican Republic; Ecuador (including Galapagos Islands); El Salvador; Fiji; French Polynesia; Grenada; Guadeloupe; Guatemala; Guyana; Haiti; Honduras; Jamaica; Kenya; Liberia; Malawi; Malaysia; Martinique; Mauritania; Mayotte; Montserrat; Mozambique; Myanmar; New Caledonia; Nicaragua; Pakistan; Panama; Papua New Guinea; Paraguay; Pitcairn Islands; Rwanda; Saint Barthelemy; Saint Helena; Saint Kitts and Nevis; Saint Martin; Saint Vincent and the Grenadines; Samoa; São Tomé and Príncipe; Seychelles; Sierra Leone; South Africa; Suriname; Tanzania; Venezuela; Wallis and Futuna; Zambia.	Angola; Benin; Burkina Faso; Burundi; Central African Republic; Congo; Côte d'Ivoire; Democratic Republic of the Congo; Gabon; Ghana; Mali; Niger; Nigeria; South Sudan; Togo.	Cameroon; French Guiana; Guinea-Bissau; Sierra Leone; Uganda.

Preliminary – Corrections Pending

Metrics and numeric limits

A modelling study based on African data sources estimated the burden of yellow fever during 2013 was 84,000-170,000 severe cases and 29,000-60,000 deaths (Garske et al., 2015).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Major epidemics of yellow fever occur when infected people introduce the virus into heavily populated areas with high mosquito density and where most people have little or no immunity, due to lack of vaccination. In these conditions, infected mosquitoes of the *Aedes aegypti* species transmit the virus from person to person (WHO, 2023).

Impacts: Yellow fever is an infectious disease transmitted by mosquitoes that bite mostly during the day. As of 2023, 34 countries in Africa and 13 countries in Central and South America are either endemic for, or have regions that are endemic for, yellow fever (WHO, 2023).

Multi-hazard Context: Yellow fever is an epidemic-prone mosquito-borne vaccine-preventable disease that is transmitted to humans by the bites of infected mosquitoes. Yellow fever is caused by an arbovirus (a virus transmitted by vectors such as mosquitoes, ticks or other arthropods) transmitted to humans by the bites of infected *Aedes* and *Haemagogus* mosquitoes. These day-biting mosquitoes breed around houses (domestic), in forests or jungles (sylvatic), or in both habitats (semi-domestic). Yellow fever is a high-impact high-threat disease, with risk of international spread, which represents a potential threat to global health security (WHO, 2023).

Monitoring: WHO recommends that every at-risk country has at least one national laboratory where basic yellow fever blood tests can be performed. A confirmed case of yellow fever in an unvaccinated population is considered an outbreak. A confirmed case in any context must be fully investigated. Investigation teams must assess and respond to the outbreak with both emergency

measures and longer-term immunization plans (WHO, 2023).

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a disaster from natural hazards. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, no date a)

Risk Management: Prompt detection of yellow fever and rapid response through emergency vaccination campaigns are essential for controlling outbreaks. However, underreporting is a concern; WHO estimates the true number of cases to be 10 to 250 times what is now being reported (WHO, 2023). The risk of yellow fever transmission in urban areas can be reduced by eliminating potential mosquito breeding sites, including by applying larvicides to water storage containers and other places where standing water collects. Both vector surveillance and control are components of the prevention and control of vector-borne diseases, especially for transmission control in epidemic situations (WHO, 2023).

Yellow fever is prevented by an extremely effective vaccine, which is safe and affordable (WHO, 2023). However, there is no specific antiviral therapy, so if severe illness develops, only supportive care is available. Vaccination is the most important measure for preventing yellow fever (WHO, no date b). Yellow fever vaccine is safe, affordable, and a single dose provides life-long protection against yellow fever disease. The yellow fever vaccine provides immunity within one week in 95% of people vaccinated. A booster dose is not needed. Yellow fever vaccination is carried out for the following reasons:

- to protect populations living in areas at high-risk or endemic for yellow fever disease;
- to protect travellers visiting these areas; and,
- to prevent international spread by minimizing the risk of importation of the virus to unaffected areas (WHO, no date b).

All currently available yellow fever vaccines are live and attenuated formulations. Vaccines from four manufacturers are currently prequalified by WHO. Yellow fever control is based on the prevention of outbreaks, and this can only be achieved if most of the population (recommended ≥80% of eligible population) is immunised in all high risk and endemic areas. It is recommended that the yellow fever vaccine be given to infants at age 9–12 months at the same time as the measles vaccine in yellow fever-endemic countries. All countries with areas at risk of yellow fever disease should aim to reach and sustain high coverage through routine immunization services. High-risk countries are recommended to establish a timeline for introduction if the vaccine has not yet been introduced. Countries at risk of yellow fever that are establishing and strengthening immunization in the second year of life (2YL) and beyond should consider yellow fever vaccination of children missed in the first year of life (WHO, no date b).

In addition, preventive mass vaccination campaigns are recommended for areas at risk of yellow fever where there is low vaccination coverage. Vaccination should be provided to everyone aged ≥9 months in any area with reported cases. Countries should aim to integrate yellow fever mass vaccination campaigns with other campaigns or interventions, where feasible (WHO, no date b).

During yellow fever epidemics, reactive vaccination campaigns are carried out with minimal delay to limit the spread of the disease. There is a global emergency yellow fever vaccine stockpile of 6 million doses (rotating stock) per year funded through Gavi. The stockpile is managed through the International Coordinating Group (ICG) for vaccine provision for yellow fever. To request access to ICG stocks, national or international health authorities should submit an application form to the ICG Secretariat (WHO Geneva), or to an ICG member agency (IRFC, MSF, UNICEF) present in the country (WHO, no date b).

The Eliminate Yellow Fever Epidemics (EYE) Strategy was developed in response to two urban yellow fever outbreaks – in Luanda (Angola) and Kinshasa (Democratic Republic of Congo), with international exportation to other countries, including China, showing that yellow fever poses a serious global threat requiring new strategic thinking. The EYE strategy is comprehensive, multi-component and multi-partner. In addition to recommending vaccination activities, it calls for building resilient urban centres, planning for urban readiness, and strengthening the application of the International Health Regulations (2005) (WHO, 2023).

Occasionally, travellers who visit yellow fever-endemic countries may carry the disease to countries free from yellow fever. In order to prevent importation of the disease, many countries require proof of vaccination against yellow fever before they will issue a visa, particularly if travellers come from, or have visited yellow fever endemic areas (WHO, 2023).

Preliminary – Corrections Pending

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0242 / BIOLOGICAL / Infectious Diseases (Human and Animal)

Zika Virus (Human)

Definition

Zika virus disease is a disease transmitted primarily by Aedes mosquitoes which can lead to complications including microcephaly and other congenital malformations and neurodevelopmental disorders (WHO, 2022a).

Reference

WHO, 2022a. Zika virus. World Health Organization (WHO). https://www.who.int/news-room/fact-sheets/detail/zika-virus , Accessed 25 May 2025.

Annotations

Synonym

ZikV infection, Zika, Zika fever, Zika virus caused disease or disorder, Zika virus disease, Zika virus disease or disorder, Zika virus infection, Zika virus infectious disease, congenital Zika syndrome, congenital Zika virus infection.

Additional scientific description

Zika virus is primarily transmitted to humans and animals through the bite of an infected mosquito from the Aedes genus, mainly A. aegypti, in tropical and subtropical regions. Aedes mosquitoes usually bite during the day, peaking during early morning and late afternoon/evening (WHO, 2022a).

Zika virus is also transmitted from mother to foetus during pregnancy, through sexual contact, transfusion of blood and blood products, and organ transplantation (WHO, 2022a).

Zika virus is a mosquito-borne virus first identified in Uganda in 1947 in a Rhesus macaque monkey followed by evidence of infection and disease in humans in other African countries in the 1950s. From the 1960s to 1980s, sporadic human infections were detected across Africa and Asia. However, since 2007 outbreaks of Zika virus disease have been recorded in Africa, the Americas, Asia and the Pacific (WHO, 2022a).

In outbreaks over the last decade, Zika virus infection was found to be associated with increased incidence of Guillain-Barré syndrome. When Zika virus emerged in the Americas, with a large epidemic in Brazil in 2015, an association between Zika virus infection and microcephaly (smaller than normal head size) was first described; there were similar findings in French Polynesia upon retrospective review. From February to November 2016, WHO declared a Public Health Emergency of International Concern (PHEIC) regarding microcephaly, other neurological disorders and Zika virus, and the causal link between Zika virus and congenital malformations was soon confirmed. Outbreaks of Zika virus disease were identified throughout most of the Americas and in other regions with established *Aedes aegypti* mosquitos. Infections were detected in travellers from active transmission areas and sexual transmission was confirmed as an alternate route of Zika virus infection (WHO, 2022a).

Cases of Zika virus disease globally declined from 2017 onwards; however, Zika virus transmission persists at low levels in several countries in the Americas and in other endemic regions. In addition, the first local mosquito-transmitted Zika virus disease cases were reported in Europe in 2019, and Zika virus outbreak activity was detected in India in 2021. To date, a total of 89 countries and territories have reported evidence of mosquito-transmitted Zika virus infection; however, surveillance remains limited globally (WHO, 2022a).

Preliminary – Corrections Pending

Symptoms are generally mild and include fever, rash, conjunctivitis, muscle and joint pain, malaise or headache. Symptoms typically last for 2 to 7 days. Most people with Zika virus infection do not develop symptoms (WHO, 2022a).

A diagnosis of Zika virus infection can only be confirmed by laboratory tests of blood or other body fluids, such as urine or semen (WHO, 2022a).

The World Health Organization (WHO) has published guidance on case classification and surveillance standards (WHO, 2016a).

Metrics and numeric limits

WHO declared a public health emergency of international concern regarding microcephaly, other neurological disorders and Zika virus from February to November 2016. Cases of Zika virus disease declined from 2017 onwards globally; however, Zika virus transmission persists at low levels in several countries in the Americas and in other endemic regions. To date, a total of 89 countries and territories have reported evidence of mosquito-transmitted Zika virus infection, however, surveillance remains limited globally (WHO, no date).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016b).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Aedes mosquitoes breed in small collections of water around homes, schools, and work sites. It is important to eliminate these mosquito breeding sites (WHO, 2022a).

Zika virus is also transmitted from mother to foetus during pregnancy, through sexual contact, transfusion of blood and blood products, and organ transplantation (WHO, no date).

Impacts: Zika virus infection during pregnancy is a cause of microcephaly and other congenital malformations in the infant, including limb contractures, high muscle tone, eye abnormalities and hearing loss. These clinical features are collectively referred to as congenital Zika syndrome. The risk of congenital malformations following infection in pregnancy remains unknown; an estimated 5-15% of infants born to women infected with Zika virus during pregnancy have evidence of Zika-related complications (3). Congenital malformations occur following both symptomatic and asymptomatic infection. Zika infection in pregnancy can also cause complications such as foetal loss, stillbirth and preterm birth (WHO, 2022a).

Zika virus infection can also cause Guillain-Barré syndrome, neuropathy and myelitis, particularly in adults and older children (WHO, 2022a).

Research is ongoing to investigate the risk and effects of Zika virus infection on pregnancy outcomes, strategies for prevention and control, and effects of infection on other neurological disorders in children and adults (WHO, 2022a).

Multi-hazard Context: Not Applicable

Monitoring: WHO supports countries to conduct surveillance and control of arboviruses through the implementation of the Global Arbovirus Initiative. Launched in 2022, the Global Arbovirus Initiative is an integrated strategic plan to tackle emerging and re-emerging arboviruses with epidemic and pandemic potential focusing on monitoring risk, pandemic prevention, preparedness, detection and response, and building a coalition of partners (WHO, 2022b).

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a disaster from natural hazards. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARS should re-integrate back into the national system (WHO, 2023).

Risk Management: Protection against mosquito bites during the day and early evening is a key measure to prevent Zika virus infection. *Aedes* mosquitoes breed in small collections of water around homes, schools, and work sites. It is important to eliminate these mosquito breeding sites, including covering water storage containers, removing standing water in

Preliminary – Corrections Pending

flowerpots, and cleaning up trash and used tyres. Community initiatives are essential to support local government and public health programs to reduce mosquito breeding sites. Health authorities may also advise the use of larvicides and insecticides to reduce mosquito populations and disease spread (WHO, 2016 a). Special attention should be given to the prevention of mosquito bites among pregnant women, women of reproductive age, and young children (WHO, 2022a).

Personal protection measures include wearing clothing (preferably light-coloured) that covers as much of the body as possible; using physical barriers such as window screens and closed doors and windows; and applying insect repellent to skin or clothing (WHO, 2022a).

Young children and pregnant women should sleep under mosquito nets if sleeping during the day or early evening. Travellers and those living in affected areas should take the same basic precautions (WHO, 2022a).

For regions with active transmission of Zika virus, all people with Zika virus infection and their sexual partners (particularly pregnant women) should receive information about the risks of sexual transmission of Zika virus. WHO recommends that sexually active men and women be counselled and offered a full range of contraceptive methods to be able to make an informed choice about whether and when to become pregnant in order to prevent possible adverse pregnancy and foetal outcomes (WHO, 2022a).

No vaccine is yet available for the prevention or treatment of Zika virus infection. Development of a Zika vaccine remains an active area of research (WHO, no date). To date, mitigation strategies continue to rely on vector control (Achee et al., 2019).

WHO supports countries to conduct surveillance and control of arboviruses through the implementation of the Global Arbovirus Initiative, which is aligned with and expands upon recommendations laid out in the Zika Strategic Response Plan (WHO, 2016c, 2022a).

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0243 / BIOLOGICAL / Infectious Diseases (Human)

Seasonal Influenza (Human)

Definition

Seasonal influenza is an acute respiratory infection caused by influenza viruses which circulate in all parts of the world with around a billion cases of seasonal influenza annually, including 3–5 million cases of severe illness. It causes 290,000 to 650,000 respiratory deaths annually (adapted from WHO, 2025).

Reference

WHO, 2025. Influenza (seasonal). World Health Organization (WHO). https://www.who.int/en/news-room/fact-sheets/detail/influenza-(seasonal) Accessed 27 May 2025.

Preliminary – Corrections Pending

Annotations

Synonym

Flu.

Additional scientific description

Seasonal influenza epidemics occur mainly during winter, from October to March in the northern hemisphere and April to September in the southern hemisphere. In tropical and subtropical countries, seasonal influenza can happen all year round (WHO, 2020). The constantly evolving nature of influenza viruses makes influenza among the top few infectious hazards with significant impact.

Seasonal influenza is most often caused by type A or B influenza viruses (WHO, 2025). Seasonal influenza outbreaks are caused by small changes on the surface of viruses that have already circulated, and to which people have some immunity (WHO, 2023).

Symptoms include sudden onset of fever, cough (usually dry), headache, muscle and joint pain, sore throat and a runny nose. The cough can be severe and can last two or more weeks. Most people recover from fever and other symptoms within a week without requiring medical attention (WHO, 2025).

Seasonal influenza can cause severe illness or death in high-risk groups, such as pregnant women, children younger than five years, people older than 65 years, and people with chronic medical conditions. People with increased risk of exposure to influenza, such as children in daycare centres and schools and workers in health-care facilities, can transmit infections to others if they become ill (WHO, 2025).

Patients who are not from a high-risk group should be managed with 'symptomatic treatment' and are advised, if symptomatic, to stay home to minimise the risk of infecting others in the community. Patients known to be at high risk for developing severe or complicated illness should be treated with antiviral drugs in addition to symptomatic treatment as soon as possible. Patients with severe or progressive clinical illness associated with suspected or confirmed influenza infection (i.e., clinical syndromes of pneumonia, sepsis or exacerbation of chronic underlying disease) should be treated with antiviral drugs as soon as possible (WHO, 2017; 2025).

Most cases of human influenza are clinically diagnosed. Collection of appropriate respiratory samples and the application of a laboratory diagnostic test is required to establish a definitive diagnosis. Laboratory confirmation of influenza virus from throat, nasal and nasopharyngeal secretions or tracheal aspirate or washings is commonly performed using direct antigen detection, virus isolation, or by reverse transcriptase-polymerase chain reaction (RT-PCR) (WHO, 2025).

The World Health Organization (WHO) recommends annual vaccination with vaccines containing updated formulations for high-risk groups ideally before the season begins. Getting vaccinated at any time during the season can still help prevent flu infections (WHO, 2020).

Metrics and numeric limits

Worldwide, annual epidemics are estimated to result in about 3 to 5 million cases of severe illness, and about 290,000 to 650,000 respiratory deaths (WHO, 2023).

In industrialized countries, most deaths associated with influenza occur among people 65 years of age or older. Clinics and hospitals can be overwhelmed during peak illness periods. Epidemics can result in high levels of absenteeism and productivity losses (WHO, 2023).

The effects of seasonal influenza epidemics in developing countries are not fully known, but research estimates that 99% of deaths in children under five years of age with influenza-associated lower respiratory tract infections are found in developing countries (WHO, 2017).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: All age groups can be affected but there are groups that are more at risk than others. People at greater risk of severe disease or complications when infected are pregnant women, children under 5 years of age, older people, individuals with chronic medical conditions (such as chronic cardiac, pulmonary, renal, metabolic, neurodevelopmental, liver or hematologic diseases) and individuals with immunosuppressive conditions/treatments (such as HIV, receiving chemotherapy or steroids, or malignancy). Health and care workers are at high risk of acquiring influenza virus infection due to increased exposure to the patients, and of further spreading particularly to vulnerable individuals. Vaccination can protect health workers and the people around them (WHO, 2025).

Impacts: There are around a billion cases of seasonal influenza annually, including 3-5 million cases of severe illness with 290,000 to 650,000 respiratory deaths annually, with 95% of deaths in children under 5 years of age with influenza-related lower respiratory tract infections being in developing countries (WHO, 2025).

Most people recover from fever and other symptoms within a week without requiring medical attention. However, influenza can cause severe illness or death, especially in people at high risk. Influenza can worsen symptoms of other chronic diseases. In severe cases, influenza can lead to pneumonia and sepsis. People with other medical issues or who have severe symptoms should seek medical care. Hospitalization and death due to influenza occur mainly among high-risk groups (WHO, 2025).

Epidemics can result in high levels of worker/school absenteeism and productivity losses. Clinics and hospitals can be overwhelmed during peak illness periods. Seasonal influenza spreads easily, with rapid transmission in crowded areas including schools and nursing homes.

In temperate climates, seasonal epidemics occur mainly during winter, while in tropical regions, influenza may occur throughout the year, causing outbreaks more irregularly (WHO, 2025).

Multi-hazard Context: Not Applicable.

Monitoring: Globally coordinated surveillance of influenza, timely sharing of influenza virus data and associated information, and innovative research are key to addressing the problem of influenza. Global influenza surveillance has been conducted through the World Health Organization (WHO) Global Influenza Surveillance and Response System (GISRS) since 1952. GISRS is a system fostering global confidence for over half a century, through effective collaboration and sharing of viruses, data and benefits based on Member States' commitment to a global public health model (WHO, 2024).

The aim of GISRS is to protect people from the threat of influenza by functioning: as a global mechanism of surveillance, preparedness and response for seasonal, pandemic and zoonotic influenza; as a global platform for monitoring influenza epidemiology and disease; and as a global alert for novel influenza viruses and other respiratory pathogens (WHO, 2024).

FluNet is a global web-based tool for influenza virological surveillance first launched in 1997. The virological data entered into FluNet, e.g. number of influenza viruses detected by subtype, are critical for tracking the movement of viruses globally and interpreting the epidemiological data. The data at country level are publicly available and updated weekly (WHO, 2024).

Risk Management: Seasonal influenza spreads easily, with rapid transmission in crowded areas including schools and nursing homes. When an infected person coughs or sneezes, droplets containing viruses (infectious droplets) are dispersed into the air and can infect persons in close proximity. The virus can also be spread by hands contaminated with influenza viruses. To prevent transmission, people should cover their mouth and nose with a tissue when coughing and wash their hands regularly (WHO, 2025).

The most effective way to prevent infection with seasonal influenza virus is vaccination. Safe and effective vaccines have been used for more than 60 years. Because the influenza virus continuously mutates, a new vaccine is required each year, and those in risk groups must again be vaccinated (Walsh, 2017). Several inactivated influenza vaccines and recombinant influenza vaccines are available in injectable form. Live attenuated influenza vaccines are available as a nasal spray (WHO, 2025).

Preliminary – Corrections Pending

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0244 / BIOLOGICAL / Infectious Diseases (Human and Animal)

zoonosis

Pandemic Influenza (Human)

Definition

Pandemic influenza is the worldwide spread of a new influenza virus to which there is little or no pre-existing immunity in the human population (WHO, 2019).

Reference

WHO, 2019. Global influenza strategy 2019-2030. Geneva: World Health Organization; 2019. Licence: CC BY-NC-SA 3.0 IGO. World Health Organization (WHO). https://iris.who.int/bitstream/handle/10665/311184/9789241515320-eng.pdf?sequence=18 Accessed 27 May 2025.

Preliminary – Corrections Pending

Annotations

Synonym

Pandemic flu.

Additional scientific description

The constantly evolving nature of the influenza virus makes influenza among the top few infectious hazards with significant impact.

At least five influenza pandemics have occurred at irregular intervals over the past 100 years and have varied widely in their severity.

Historically the most catastrophic influenza pandemic occurred in 1918–1920 (the so-called “Spanish Flu”) and killed an estimated 50 million people worldwide. The other two influenza pandemics of the 20th century (in 1957 and 1968) each killed upwards of one million people (WHO EURO, no date).

In 1996, the highly pathogenic avian influenza H5N1 virus was first identified in domestic waterfowl in Southern China. The virus is named A/goose/Guangdong/1/1996. In 1997, H5N1 poultry outbreaks happened in China and Hong Kong with 18 associated human cases (6 deaths) in Hong Kong. This virus would go on to cause more than 860 human infections with a greater than 50% death rate. The virus spread quietly and was detected by Korea in imported duck meat from China in 2003 (CDC, 2024). A human case was confirmed in Vietnam on 13 January 2004 (WHO, 2004) and after Vietnam reported the case, countries reported HPAI one after another.

The 2009 H1N1 influenza pandemic is estimated to have caused up to 575 000 deaths, not only among those at a higher risk of complications but also in otherwise healthy individuals. Due to the nature of influenza viruses, a future influenza pandemic is inevitable and preparedness for it is vital. Since the re-emergence of highly pathogenic avian influenza A(H5N1) in 2002-2003, the world has accelerated its preparations for the next influenza pandemic (WHO, no date; WHO EURO, no date).

However, in 2019, a novel coronavirus (SARS-CoV-2) emerged and caused the COVID-19 pandemic. The subsequent enormous human, societal and economic costs provided a stark reminder that while the threat of an influenza pandemic remains very real, the threats posed by other respiratory viruses must also remain very much on our radar, and corresponding preparedness efforts that go beyond influenza preparedness must now be recognized as absolutely vital (WHO, no date).

However, in 2019, a novel coronavirus (SARS-CoV-2) emerged and caused the COVID-19 pandemic. The subsequent enormous human, societal and economic costs provided a stark reminder that while the threat of an influenza pandemic remains very real, the threats posed by other respiratory viruses must also remain very much on our radar, and corresponding preparedness efforts that go beyond influenza preparedness must now be recognized as absolutely vital.

The current status of knowledge and technology means that predicting the next influenza pandemic – when, where, which virus strain, and how severe it will be – is impossible. Consequently, pandemic vaccines cannot be developed before the pandemic virus emerges. The World Health Organisation (WHO) public health research agenda for influenza as an innovative research mechanism is key to inform and advance pandemic influenza preparedness (WHO, 2018).

WHO, with support from numerous experts around the world, has continued to develop and update its comprehensive range of guidelines, tools and other resources to support countries in their preparedness activities for influenza pandemics and for pandemics caused by other respiratory viruses. Such resources now include (WHO, no date):

- Influenza pandemic preparedness planning
- Pandemic preparedness planning for influenza and other respiratory virus threat
- Public health and social measures (PHSM) during a pandemic
- Surveillance during an influenza pandemic.

Metrics and numeric limits

In 2011, the IHR Review Committee on Pandemic Influenza (H1N1) 2009 recommended WHO develop and apply measures that can be used to assess the severity of every influenza epidemic: "By applying, evaluating and refining tools to measure severity every year, WHO and Member States can be better prepared to assess severity in the next pandemic."

The updated WHO pandemic influenza severity assessment (PISA) framework set out in this document provides a systematic approach for interpreting data collected through existing surveillance systems and improving their usefulness for risk communication and decision-making. The approach enables the severity of current influenza and syndromic respiratory illness activity to be assessed relative to previous years by using historical data to set thresholds that then allow for the qualitative categorization of such activity. PISA is designed to be implemented continuously based on stable/routine reporting systems, enabling activity during epidemic and pandemic periods to be compared. Information to assess severity especially early and throughout the course of a pandemic will also be provided through investigations, studies and modelling (WHO, 2024a).

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: A pandemic occurs when an influenza virus emerges to which there is little or no immunity in the global human population and which can transmit efficiently among people. The pandemic virus can be a virus strain jumping directly from animals or reassorted from animal viruses with or without human seasonal viruses (WHO, no date a, WHO EURO, no date).

Impacts: Influenza pandemics, whether mild, moderate or severe, affect a large proportion of the global population, which puts significant strains on health and other essential services and may result in significant economic losses (WHO, no date a).

WHO recommends annual vaccination for high-risk groups including health care workers. People should ideally get vaccinated just before the influenza season begins for the most effective coverage, although getting vaccinated at any time during the influenza season can still help prevent flu infections. The best way to avoid getting the flu is to get the flu vaccine every year. Influenza viruses evolve constantly, and twice a year WHO makes recommendations to update the vaccine compositions. For the 2016-2017 northern hemisphere influenza season, the vaccine formulation was updated in February 2016 to contain two type A viruses (H1N1 and H3N2), and a type B virus (WHO, 2020).

In 2018, the world observed the centenary of the start of the 1918-1919 influenza pandemic. Its estimated toll of up to 50 million deaths exceeded that of the First World War, resulting in a dramatic decline in life expectancy in many countries at the time of the pandemic. Its impact led to fundamental changes in public health and health-care systems, including centralized and consolidated health-care, greater recognition of the role of socioeconomics in health, and the coordination of public health at national and global levels.

Since the 1918-1919 pandemic, there has been significant progress in medical science, including the development of influenza vaccines, antiviral drugs and better diagnostics. Subsequent pandemics occurred in 1957-1958, 1968-1969 and 2009-2010, resulting in 1-4 million, 1-4 million and 100 000-400 000 deaths, respectively.

The pandemic (H1N1) 2009 caused significant deaths, particularly in those aged under 65 years; it also tested national health response systems, in particular, the pandemic vaccine response capacity) and exposed weaknesses in those systems. It reiterated that influenza viruses of both avian and swine origin can cause a pandemic, and it underscored the importance of intersectoral collaboration for pandemic preparedness.

Although it is impossible to predict when the next pandemic might occur, its occurrence is considered inevitable, and it could well occur during the time frame of this strategy. Given increased economic globalization, urbanization and mobility, the next pandemic will spread further and faster and could lead to significant disruptions. Despite significant medical advances over the past 100 years, there will still be populations that have limited access to care and will be likely to experience high mortality rates during a pandemic.

Multi-hazard Context: Not Applicable.

Preliminary – Corrections Pending

Monitoring: Global influenza surveillance has been conducted through WHO's Global Influenza Surveillance and Response System (GISRS) since 1952 (WHO, 2924b). GISRS is a system fostering global confidence and trust for over half a century, through effective collaboration and sharing of viruses, data and benefits based on Member States' commitment to a global public health model.

The mission of GISRS is to protect people from the threat of influenza by continuously functioning as a:

- global mechanism of surveillance, preparedness and response for seasonal, pandemic and zoonotic influenza;
- global platform for monitoring influenza epidemiology and disease; and
- global alert for novel influenza viruses and other respiratory pathogens.

The table below offers an overview of monitoring for pandemic influenza. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	WHO, Ministry of Health, FAO Reference Centres, WOAH Reference Centres, CDC
How is the Hazard Observed/Monitored/Forecast?	FAO empres-i+ https://empres-i.apps.fao.org/diseases WHO Risk assessments and summaries of influenza at the human-animal interface https://www.who.int/teams/global-influenza-programme/avian-influenza/monthly-risk-assessment-summary (TIPRA) WHO WPRO https://www.who.int/westernpacific/wpro-emergencies/surveillance/avian-influenza WOAH WAHIS https://wahis.woah.org/#/event-management CDC IRAT

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, no date b).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARSs should re-integrate back into the national system (WHO, no date, b).

Risk Management: Timely detection, characterisation and sharing of information about the pandemic virus directly affects the outcome of all downstream responses. The WHO GISRS is the foundation of such an operation. In an influenza pandemic, the virus is likely to spread rapidly. Rapid development, production and deployment of vaccines are critical to limit the potential impact on populations and essential services. Access to the appropriate vaccine in the early phases of a pandemic is greatly influenced by global production capacity and the lead time required to produce influenza vaccines (WHO, no date a).

As an influenza pandemic may last months or even years, it may require a sustained response in the health sector but also in other sectors providing essential services, such as energy and food production (WHO, no date a; WHO; 2025 b).

The Pandemic Influenza Preparedness Framework, or PIP Framework, is an innovative access and benefit-sharing instrument that seeks to better prepare the world to respond more equitably to the next influenza pandemic. The PIP Framework was adopted on 24 May 2011 by the 194 Member States of WHO, recognizing that an influenza pandemic would be a global challenge, and preparing for it requires a holistic, collective and cooperative approach. WHO implements the PIP Framework in close partnership with Member States and public health laboratories that are specialized in influenza, industry and civil society. The PIP Framework enables the sharing by WHO Member States of influenza viruses with human pandemic potential with the Global Influenza Surveillance and Response System (GISRS) and equitable access to vaccines, medicines and other products and technologies. Under the Framework, Member States are expected to share their influenza viruses with pandemic potential (IVPPs) in a rapid, systematic and timely manner with GISRS, a WHO-coordinated global network of public health laboratories. In addition to serving as a virus-sharing platform, GISRS also develops - *inter alia* - candidate vaccine viruses, and other analyses, materials and information that are shared with Member States and manufacturers of influenza vaccines and other products, such as antivirals and diagnostics (WHO, 2024a).

Globally coordinated surveillance of influenza, timely sharing of influenza virus data and associated information, and innovative research are key to addressing the problem of influenza. Global influenza surveillance has been conducted through the World Health Organization (WHO) Global Influenza Surveillance and Response System (GISRS) since 1952. GISRS is a system fostering global confidence for over half a century, through effective collaboration and sharing of viruses, data and benefits based on Member States' commitment to a global public health model (WHO, 2024b).

Preliminary – Corrections Pending

The aim of GISRS is to protect people from the threat of influenza by functioning: as a global mechanism of surveillance, preparedness and response for seasonal, pandemic and zoonotic influenza; as a global platform for monitoring influenza epidemiology and disease; and as a global alert for novel influenza viruses and other respiratory pathogens (WHO, 2024b).

One Health measures to mitigate the risk of pandemic influenza adapting to mammals and humans focus on limiting exposure and preventing spread. Key options for actions include enhancing surveillance targeting humans and animals, ensuring access to rapid diagnostics, promoting collaboration between animal and human sectors, and considering the implementation of preventive measures such as vaccination of poultry. Effective communication with different target audiences should be emphasised, as well as strengthening veterinary infrastructure, enforcing biosecurity measures at farms, and reducing wildlife contact with domestic animals (EFSA & ECDC, 2024).

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0245 / BIOLOGICAL / Infectious Diseases (Human and Animal)

zoonosis

Avian Influenza (Human and Animal)

Definition

Avian influenza is an infectious disease of birds caused by type A influenza viruses of the *Orthomyxoviridae* family. Naturally occurring among wild bird populations, avian influenza viruses can infect domestic poultry and other bird species. Some avian influenza viruses can also infect mammals and those affecting humans are called zoonotic. A pandemic can occur when a novel influenza virus spreads in human populations worldwide (adapted from FAO, 2009; WHO, 2023a; 2023b; WOAH, no date).

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Annotations

Synonyms

Bird Flu, Avian Flu, HPAI (en), influenza aviaire, grippe aviaire (fr), influenza aviar, gripe aviar (es), 禽流感 (cn).

Additional scientific description

Human

- Avian influenza is transmitted by direct contact with infected birds or through contaminated environments (farms, markets, cages, vehicles, etc.) (WOAH, no date). Live poultry and poultry products trade and movements play an important role in national and cross-border spread. Certain avian influenza strains have also been shown to spread through migratory wild bird movements, sometimes over long distances (FAO, 2016, 2017). Biosecurity measures on farms and in live poultry markets are important to prevent disease introduction or spread (FAO, 2015).
- Type A influenza viruses include many different subtypes, classified according to the nature of the two components that make up the virus — haemagglutinin (H) and neuraminidase (N) — proteins found on the surface of influenza viruses. There are 18 haemagglutinin and 11 neuraminidase subtypes of influenza A virus, giving rise to hundreds of variations on the 'HxNy' combination. Since the emergence of the H5N1 Highly Pathogenic Avian Influenza (HPAI) virus subtype in 1997 in Asia, several other subtypes have appeared due to the constant evolution and diversification of avian influenza viruses and progressively spread across continents (WOAH, 2016; CDC, 2017).
- In 1997, human infections with A(H5N1) viruses were reported during an outbreak in poultry in Hong Kong SAR, China. Since 2003, this virus has spread in bird populations from Asia to Europe and Africa, and to the Americas in 2021, and has become endemic in poultry populations in many countries. Outbreaks have resulted in millions of poultry infections, several hundred human cases and many human deaths. Human cases have been reported mostly from countries in Asia, but also from countries in Africa, the Americas and Europe (WHO, 2023).
- In 2013, human infections with A(H7N9) viruses were reported for the first time in China. The virus spread in the poultry population across the country and resulted in over 1500 reported human cases and many human deaths from 2013 to 2019. No

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further human cases have been reported to WHO since 2019. Since 2014, sporadic human infections with avian influenza A(H5N6) viruses have been reported almost exclusively from China. Other avian influenza viruses have resulted in sporadic human infections (WHO, 2023).

Animal

Avian influenza is preventable through control measures, including vaccination. As avian influenza viruses antigenically change over time, the use of appropriately matched vaccines is important (OFFLU, 2023). Each country has a policy in handling avian influenza, especially on vaccination. Countries permitting vaccination in poultry have a list of approved vaccines. Contact national veterinary services to learn what is allowed in the country before purchasing.

- Highly pathogenic avian influenza (HPAI) causes variable clinical signs and high mortality rates in both wild and domestic bird populations. In certain bird species, some HPAI viruses do not necessarily produce significant clinical disease (WOAH, 2024a).
- Avian influenza viruses can infect domestic poultry and other bird species; some avian influenza viruses can also infect mammals.
- AIV has been shown to infect domestic mammals such as cats and cattle, as well as wild mammals including terrestrial (e.g. foxes, skunks, raccoons) and marine species (e.g., seals, sea lions) (FAO, no date).
- Avian influenza is transmitted by direct contact with infected birds or through contaminated environments (farms, markets, cages, vehicles, etc.).
- Live poultry and poultry products trade and movements play an important role in national and cross-border spread. Certain avian influenza viruses have also been shown to spread through migratory wild bird movements, sometimes over long distances. Biosecurity measures on farms and in live poultry markets are important to prevent disease introduction or spread (FAO, 2015).
- Highly pathogenic avian influenza (HPAI) is one of the WOAH Listed diseases (WOAH, 2024b).
- Avian influenza viruses of the H5 and H7 subtypes, as well as any influenza A virus with high pathogenicity are notifiable to the World Organization for Animal Health (WOAH) under the Terrestrial Animal Health Code.

Metrics and numeric limits

Strains are considered to be of high pathogenicity if they cause more than 75% mortality within 10 days, or inoculation of 10 susceptible 4- to 8-week-old chickens resulting in an intravenous pathogenicity index (IVPI) of greater than 1.2. (WOAH, 2024a).

Key relevant UN convention / multilateral treaty

United Nations, 2023. UN Model Regulations Rev. 23. United Nations. https://unece.org/transport/dangerous-goods/un-model-regulations-rev-23 Accessed 1 January 2025.

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Examples of hazard drivers, impacts, and risk management

Human

Hazard Drivers: For avian influenza viruses, the primary risk factor for human infection appears to be exposure to infected live or dead poultry or contaminated environments, such as live bird markets. Slaughtering, defeathering, handling carcasses of infected poultry, and preparing poultry for consumption, especially in household settings, are also likely to be risk factors. There is no evidence to suggest that A(H5), A(H7N9) or other avian influenza viruses can be transmitted to humans through properly prepared and cooked poultry or eggs. A few influenza A (H5N1) human cases have been linked to the consumption of dishes made with raw contaminated poultry blood.

Impacts: Exposure to avian influenza viruses can lead to infection and disease in humans, ranging from mild, flu-like symptoms or eye inflammation to severe, acute respiratory disease and/or death. Disease severity will depend upon the virus causing the infection and the characteristics of the infected individual. Rarely, gastrointestinal and neurological symptoms have been reported. The case fatality rate for A(H5) and A(H7N9) subtype virus infections among humans is higher than that of seasonal influenza infections (WHO, 2023). An influenza pandemic will occur when an influenza virus emerges with the ability to cause sustained human-to-human transmission, and the human population has little to no immunity against the virus. With the growth of global travel, a pandemic can spread rapidly. Whether currently circulating avian, swine and other influenza viruses will result in a future pandemic is unknown. However, the diversity of zoonotic influenza viruses that have caused human infections necessitates strengthened surveillance in both animal and human populations, thorough investigation of every zoonotic infection and pandemic preparedness planning. Influenza viruses are impossible to eradicate, and zoonotic infections will continue to occur.

Since 1997 several studies have contributed to fundamental insights into the pathology and pathogenesis of human H5N1 influenza. Aside from the respiratory tract, other organs such as the intestines, the brain, and the placenta appear to be infection targets of the virus. The H5N1 virus is also capable of transplacental transmission to the foetus. Dysfunction of the immune system may be a key pathogenetic mechanism. At the molecular level, several viral genes and mutations in gene products have been suggested to be involved in increased virulence of H5N1 viruses. At the same time, however, it becomes increasingly apparent that what is known today about the virus and its pathogenicity is only the tip of the iceberg and that there are likely several additional pathogenetic mechanisms and molecular determinants of pathogenicity in H5N1 influenza yet to be identified (Korteweg et al., 2008).

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Animal
Hazard Drivers: Introduction of an avian influenza virus to a susceptible flock via poultry trade-related activities or farming and sale (live bird markets), or wild birds and migratory routes (WOAH, no date).
Impacts: Animal influenza outbreaks have the potential to be significant to public health and can have social and economic impacts (WHO, 2024d). Losses of rare and important wild bird species, as well as significant social and economic costs, including livelihood losses and egg shortages (FAO, no date). High mortality in poultry with sudden death of birds, may cause severe illness in humans, stamping-out of birds in the affected flock or farm, poultry movement restrictions, trade ban, livelihoods, food security and health implications, in particular women and children who often are the ones caring for poultry (WOAH, no date).

Multi-hazard Context: Not Applicable.

Monitoring: The table below offers an overview of monitoring for harmful algal blooms. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	WHO, Ministry of Health, FAO Reference Centres, WOAH Reference Centres
How is the Hazard Observed/Monitored/Forecast?	FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

Through its Global Influenza Surveillance and Response System (GISRS). WHO, in collaboration with the World Organisation for Animal Health (WOAH) and the Food and Agriculture Organization of the United Nations (FAO), conducts surveillance at the human-animal interface, assesses the associated risks and coordinates response to zoonotic influenza outbreaks and other threats to public health (WHO, 2023)

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country's risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARSs should re-integrate back into the national system (WHO, no date a).

Human
To minimize public health risks, quality surveillance in both animal and human populations, thorough investigation of every human infection and risk-based pandemic planning are essential. Public health and animal health authorities should work together and share information during investigations of human cases of zoonotic influenza (WHO, 2023).
The public should minimize contact with animals in areas known to be affected by animal influenza viruses, including farms and settings where live animals may be sold or slaughtered, and avoid contact with any surfaces that appear to be contaminated with animal faeces. Children, older people, pregnant and postpartum women (up to 6 weeks) or people with suppressed immune systems should neither collect eggs nor assist with slaughtering or food preparation. Travellers to countries and people living in countries with known outbreaks of avian influenza should, if possible, avoid poultry farms, contact with animals in live poultry markets, entering areas where poultry may be slaughtered, and contact with any surfaces that appear to be contaminated with faeces from poultry or other animals. Travellers returning from affected regions should report to local health services if respiratory symptoms suspecting zoonotic influenza virus infection (WHO, 2023).
Global influenza surveillance has been conducted through WHO's Global Influenza Surveillance and Response System (GISRS) since 1952. GISRS currently comprises institutions in 129 WHO Member States. The mission of GISRS is to protect people from the threat of influenza by continuously functioning as a global mechanism of surveillance, preparedness and response for seasonal, pandemic and zoonotic influenza; global platform for monitoring influenza epidemiology and disease; and global alert for novel influenza viruses and other respiratory pathogens (WHO, 2024; WHO, no date b).
Twice a year, WHO consults with experts from WHO Collaborating Centres, Essential Regulatory Laboratories and other partners to review data generated by GISRS and animal health partners on influenza viruses with pandemic potential and assesses the need for additional candidate vaccine viruses for pandemic preparedness purposes. Based on risk assessment, WHO provides guidance, develops and adjusts surveillance, preparedness and response strategies to seasonal, zoonotic and pandemic influenza, and communicates timely risk assessment outcomes and intervention recommendations with Member States to enhance preparedness and response nationally and globally. The WHO Pandemic Influenza Preparedness Framework implements a global approach to prepare for the next influenza pandemic (WHO, 2023).
Animal
Farm and market biosecurity improvement, movement control, depopulation, tracing back/forward, vaccination (prevention, only if the country allows vaccination of birds against avian influenza), compartmentalisation, food hygiene (WOAH, no date).

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Coordinating agency or organisation

Food and Agriculture Organization of the United Nations (FAO), World Health Organization (WHO), World Organisation for Animal Health (WOAH).

Preliminary – Corrections Pending

BI0301 / BIOLOGICAL / Infectious Diseases (Animal)

Infectious Animal Diseases (Not Zoonoses)

Definition

Non-zoonotic infectious animal diseases are not shared between animals and humans (WHO, FAO, & OIE, 2019).

Reference

WHO, FAO & OIE, 2019. Taking a Multisectoral, One Health Approach: a Tripartite Guide to Addressing Zoonotic Diseases in Countries. World Health Organization (WHO), Food and Agriculture Organization of the United Nations (FAO), World Organisation for Animal Health (WOAH). https://iris.who.int/handle/10665/325620 Accessed 9 January 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Anthroponoses. Anthroponotic animal diseases, Species-specific diseases.

Additional scientific description

Animals also fall sick for various reasons. Some of these diseases can infect humans and are called zoonosis (BI0113); some are not infectious such as milk fever in cows caused by a shortage of calcium, or onion poisoning in cats, which occurs due to a specific dietary cause. Of the infectious diseases that infect various livestock species, some are called Transboundary Animal Diseases (TADs). TADs can easily spread to other countries and reach epidemic proportions, their control/management requires cooperation between several countries (FAO, 2009). Moreover, TADs pose a serious threat to world food security through their capacity to spread very rapidly in plague proportions and cause critical shortfalls in the production of milk, meat and other animal-derived human foodstuffs (FAO, 1997).

Example of major TADs in HIPs: African swine fever (BI0302), classical swine fever (BI0303), contagious bovine pleuropneumonia (BI0304), foot-and-mouth disease (BI0306), lumpy skin disease (BI0307), peste des petits ruminants (BI0310), Rift Valley fever (BI0311), rinderpest (BI0312).

Metrics and numeric limits

Not applicable.

Key relevant UN convention / multilateral treaty

United Nations. 2023. UN Recommendations on the Transport of Dangerous Goods - UN Model Regulations. https://unece.org/transport/dangerous-goods/un-model-regulations-rev-23 Accessed 1 January 2025.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Hazard drivers of non-zoonotic infectious animal diseases include movement of animals, vectors and climate change, floods and swill feeding. For example, feeding swill (consumption phase food waste) is historically associated with disease transmission to animals (Dame-Korevaar et al., 2021).

Impacts: Non-zoonotic infectious animal diseases are threats to the lives of animals and to food security and biodiversity.

Multi-hazard Context: Not Applicable.

Monitoring: The section and the table below offer an overview of monitoring for infectious animal diseases. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	FAO Reference Centres, WOAH Reference Centres
How is the Hazard Observed/Monitored/Forecast?	FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

Risk Management: vaccination, biosecurity

References

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Dame-Korevaar A., Boumans I. J. M. M. Adriaan F.G. Antonis A. et al., 2021. Microbial health hazards of recycling food waste as animal feed. Future Foods. Vol 4. 100062. ISSN 2666-8335. https://doi.org/10.1016/j.fufo.2021.100062 Accessed 25 May 2025.

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Coordinating agency or organisation

United Nations Food and Agricultural Organization (FAO), World Organisation for Animal Health (WOAH).

Preliminary – Corrections Pending

BI0302 / BIOLOGICAL / Infectious Diseases

African Swine Fever (Animal)

Definition

African swine fever (ASF) is a highly contagious viral disease of domestic and wild pigs, whose mortality rate can reach 100%. It is not a danger to human health, but it has devastating effects on pig populations and the farming economy. (WOAH, no date).

Reference

WOAH, no date. African swine fever. World Organisation for Animal Health (WOAH). https://www.woah.org/en/disease/african-swine-fever/ Accessed 28 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Peste porcine africaine (fr), peste porcina Africana (es)

Additional scientific description

African Swine Fever (ASF) is a highly contagious, generalized disease of pigs caused by an Iridovirus of the family *Asfarviridae* that exhibits varying virulence between strains and is very hardy to physical and chemical inactivation. The agent can remain viable for long periods in blood, faeces and tissues. It can also multiply in its vectors. In view of this, control of ASF is dependent on stamping-out policy and strict quarantine enforcement (FAO, 2019).

In the natural sylvatic cycle, the soft-bodied, eyeless *Ornithodoros* ticks (also known as tampans) are, together with African wild suids, the natural reservoir hosts of ASFV. They can transmit the virus through their bites. All members of the pig family (Suidae) are susceptible to infection, but clinical disease is only seen in domestic and feral pigs, as well as in the closely related European wild boar. Wild African suids are asymptomatic carriers of ASF and act as the reservoir of the virus in parts of Africa. These include warthogs (*Phacochoerus africanus* and *P. aethiopicus*), bushpigs (*Potamochoerus porcus* and *P. larvatus*) and giant forest hogs (*Hylochoerus meinertzhageni*) (FAO, 2019).

In domestic pigs, ASF is transmitted mainly through direct contact, via the oronasal route, through excretions from infected pigs, or from ingestion of pork or other contaminated products containing the virus (e.g. swill, waste, carcasses, etc.). Further transmission pathways are indirect contact through fomites or vector-borne transmission through bites from infected *Ornithodoros* soft ticks, where present.

It most commonly appears in the acute form of a haemorrhagic fever. Subacute and chronic forms of the disease also exist. Mortality is usually close to 100% and pigs of all ages are affected (FAO, 2019).

In subacute and chronic cases, pigs may show milder clinical signs, such as loss of appetite, weight loss, and fever (Sánchez-Vizcaíno et al., 2015; Sun et al., 2021).

ASF is present in wild and/or domestic pigs in regions of Asia, Europe and Africa (OIE, 2018). People can transport the virus over large distances through contaminated meat and other sub-products such as skins, skulls, tusks or other hunting trophies (OIE, 2018; FAO, OIE & EC, 2019).

There are no commercial vaccines available for ASF. Some vaccine trials have been implemented in the Philippines and Vietnam. Most countries maintain a list of approved veterinary vaccines for use. For specific regulations, consult the country's veterinary authorities.

ASF is one of the World Organisation for Animal Health (WOAH) listed diseases (WOAH, 2024b).

The disease is not a zoonosis, i.e. it does not infect humans.

Metrics and numeric limits

An estimated quarter of the global domestic pig population has been decimated by the disease, causing food insecurity and economic losses on an unprecedented global scale (Dixon et al, 2019)

Key relevant UN convention / multilateral treaty

WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) (WTO, 1994). https://www.wto.org/english/res_e/booksp_e/agrmntseries4_sps_e.pdf

UN Recommendations on the Transport of Dangerous Goods - UN Model Regulations Model Regulations (UNECE, 2023). https://unece.org/transport/dangerous-goods/un-model-regulations-rev-23

Examples of drivers, impacts, and risk management

Hazard Drivers: lack of biosecurity, swill feeding and transport of live pigs and uncooked port products, presence of the competent vector ticks of the genus *Ornithodorous*.

ASF easily spreads in areas experiencing storms, flooding, civil conflict, insecurity, displacement of people, or agreater need to remain mobile, due to difficulties in maintaining high biosecurity. Pork products for food aid may introduce ASF to ASF-free areas when uncooked food waste is fed to raise pigs

Impacts: death of infected animals, spread of infection and trade ban. The disease is the cause of major economic losses, threatens food security and safe trade, and challenges sustained swine production in affected countries.

Multi-hazard Context: Pork meat is one of the primary sources of animal proteins, accounting for more than 35% of the global meat intake. Hence, this disease poses a serious problem for food security worldwide (WOAH, no date).

ASF continues to spread worldwide, threatening pig health and welfare. The disease has reached multiple countries across Asia, the Caribbean, Europe, and the Pacific, affecting both domestic and wild pigs (WOAH, no date).

This disease is also a concern for biodiversity and the balance of ecosystems, as it affects not only domestic farmed pigs but also wild boars, including native breeds (WOAH, no date).

Monitoring: The section and the table below offer an overview of monitoring for African swine fever. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	FAO Reference Centres, WOAH Reference Centres,
How is the Hazard Observed/Monitored/Forecast?	FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

Risk Management: Measures include depopulate infected herds, movement control, improving biosecurity at farms. A One Health approach to risk management will help address interconnected factors contributing to risk and promoting collaboration across sectors while enhancing surveillance and early warning through integrating human, animal, and environmental health.

References

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Sun, E., Huang, L., Zhang, X., Zhang, J., Shen, D., Zhang, Z., Wang, Z., *et al.* 2021. Genotype I African Swine Fever Viruses Emerged in Domestic Pigs in China and Caused Chronic Infection. *Emerg. Microbes Infect*, 10:2183-2193. doi: 10.1080/22221751.2021.1999779

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Preliminary – Corrections Pending

WTO, 1998. The WTO and the World Organization for Animal Health (WOAH). G/SPS/GEN/775. World Trade Organization (WTO). https://www.wto.org/english/thewto_e/coher_e/wto_oie_e.htm Accessed 1 September 2024.

Coordinating agency or organisation

Food and Agriculture Organization of the United Nations (FAO) and World Organization for Animal Health (WOAH).

Preliminary – Corrections Pending

BI0303 / BIOLOGICAL / Infectious Diseases

Classical Swine Fever (Animal)

Definition

Classical swine fever, also known as hog cholera, is a contagious viral disease of domestic and wild swine. It is caused by a virus of the genus *Pestivirus* of the family Flaviviridae (WOAH, no date).

Reference

WOAH, no date. Classical Swine Fever (CSF). World Organisation for Animal Health (WOAH). https://www.woah.org/en/disease/classical-swine-fever/ Accessed 28 May 2025.

Annotations

Synonyms

Hog cholera

Additional scientific description

Classical swine fever (CSF) remains one of the most important transboundary viral diseases of swine worldwide. Classical Swine Fever (CSF) is a contagious viral disease of domestic and wild swine. It is caused by a virus of the genus *Pestivirus* of the family *Flaviviridae* (WOAH, 2022). The disease is preventable through control measures, including vaccination. The CSF vaccine provides a good example of solid immunity. Each country typically maintains a list of registered veterinary vaccines approved for use. For specific regulations, consult the country's veterinary authorities.

The disease has acute and chronic forms and can range from severe, with high mortality, to mild or even unapparent. In the acute form of the disease, in all age groups, there is fever, huddling of sick animals, loss of appetite, dullness, weakness, conjunctivitis, constipation followed by diarrhoea, and an unsteady gait. Several days after the onset of clinical signs, the ears, abdomen and inner thighs may show purple discolouration. Animals with acute disease die within one to two weeks. Severe cases of the disease appear very similar to African swine fever. With low virulence strains, the only expression may be poor reproductive performance and the birth of piglets with neurological defects such as congenital tremors. The most common method of transmission is through direct contact between healthy swine and those infected with classical swine fever virus (CSFV). The virus is shed in saliva, nasal secretions, urine, and faeces. Contact with contaminated vehicles, pens, feed, or clothing may spread the disease. Animals that are chronic carriers of the disease (persistently infected) may show no clinical signs of illness but may shed the virus in their faeces. Offspring of infected sows can become infected in the uterus and once born can shed the virus for months. CSFV can survive in pork and processed pork products for months when meat is refrigerated and for years when it is frozen. Pigs can become infected by eating CSF-infected pork meat or products.

CSF is found in Central and South America, Europe, Asia, and parts of Africa. North America, Australia and New Zealand are currently free of the disease. In the 1990s large CSF outbreaks occurred in the Netherlands, Germany, Belgium and Italy. The World Organisation for Animal Health standards for surveillance have helped eradicate CSF from North America and much of Western Europe. It has been proven that in parts of Europe; the wild boar population may play a role in the epidemiology of the disease. The disease has been spread through legal and illegal transport of animals, and by feeding swill containing infective tissues to pigs. When an outbreak occurs, many actions must be set in place urgently: slaughter of all pigs on affected farms; safe disposal of carcasses, bedding, etc.; thorough disinfection; designation of infected zone, with control of pig movements; detailed epidemiological investigation, with tracing of possible sources (up-stream) and surveillance of the infected zone, and the surrounding area. In disease-free areas, a stamping-out policy is applied consisting of early detection, movement control, proper disposal of carcasses, and cleaning and disinfection. This policy has led to the elimination of CSF from North America, and much of Western Europe (WOAH, no date).

In areas where the disease is endemic, vaccination can prevent the spread of the disease. Vaccines used should be produced in accordance with the OIE standards for vaccine production (WOAH, 2024a). As the disease is brought under control, vaccination ceases, with continued surveillance. The WOAH Terrestrial Animal Health Code defines the requirements for a country or a zone to be considered free of the disease. CSF is one of the World Organisation for Animal Health (WOAH) listed diseases (WOAH,

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2024b). The disease is not a zoonosis, i.e. it does not infect humans.

Metrics and numeric limits

CSF is one of the World Organisation for Animal Health (WOAH) listed diseases (WOAH, 2024b). Reports are available on organisations such as the World Organisation for Animal Health map of CSF official status (WOAH) website (WOAH, 2024c) and the Swine Health Information Center (SHIC, 2024)

Key relevant UN convention / multilateral treaty

WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) (WTO, 1994). https://www.wto.org/english/res_e/booksp_e/agrmntseries4_sps_e.pdf

United Nations. 2023. UN Recommendations on the Transport of Dangerous Goods - UN Model Regulations. https://unece.org/transport/dangerous-goods/un-model-regulations-rev-23

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: lack of biosecurity, swill feeding. CSF easily spreads in areas experiencing storms, flooding, civil conflict, insecurity, displacement of people, and greater need to remain mobile, due to difficulties in maintaining high biosecurity. Pork products for food aid may introduce CSF to CSF-free areas when uncooked food waste is fed to raise pigs.

Impacts: Death of infected animals, spread of infection, trade ban. An outbreak in the Netherlands in 1997 led to the destruction of 11 million pigs and cost USD 2.3 billion (WOAH, 2024a).

Multi-hazard Context: The virus is shed in saliva, nasal secretions, urine, and faeces. Contact with contaminated vehicles, pens, feed, or clothing may spread the disease. Animals that are chronic carriers of the disease (persistently infected) may show no clinical signs of illness but may shed the virus in their faeces. It has been proven that in parts of Europe, the wild boar population may play a role in the epidemiology of the disease. The disease has been spread through legal and illegal transport of animals, and by feeding swill containing infective tissues to pigs (WOAH, no date).

Monitoring: The section and the table below offer an overview of monitoring for classical swine fever. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	FAO Reference Centres, WOAH Reference Centres,
How is the Hazard Observed/Monitored/Forecast?	FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

Risk Management: Vaccination programme, movement control, depopulating infected herds, improvement of biosecurity at farms. CSF disease prevention and control states that treatment if not attempted, affected pigs must be slaughtered and the carcases buried or incinerated. The first barrier preventing a CSF outbreak is to apply strict and rigorous sanitary prophylaxis, as defined in the WOAH Terrestrial Animal Health Code (WOAH, 2024b). Good communication between veterinary authorities, veterinary practitioners and pig farmers, a reliable disease reporting system, and hygiene measures protecting domestic pigs from contact with wild boar are the most effective measures to prevent the disease

References

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WOAH, 2024b. Terrestrial Animal Health Code. 32nd edition. World Organisation for Animal Health (WOAH). https://www.woah.org/en/what-we-do/standards/codes-and-manuals/terrestrial-code-online-access/index.php?id=169&L=1&htmfile=chapitre_selfdeclaration_CSF.htm Accessed 1 January 2025.

WOAH, 2024c. Official Disease Status and Map of CSF official status. World Organisation for Animal Health (WOAH). https://www.woah.org/en/disease/classical-swine-fever/#ui-id-2 Accessed 28 May 2025.

WOAH, no date. Classical Swine Fever (CSF). World Organisation for Animal Health (WOAH).

Preliminary – Corrections Pending

https://www.woah.org/en/disease/classical-swine-fever/ Accessed 28 May 2025.

Coordinating agency or organisation

Food and Agriculture Organization of the United Nations (FAO) and World Organization for Animal Health (WOAH).

Preliminary – Corrections Pending

BI0304 / BIOLOGICAL / Infectious Diseases

Contagious bovine pleuropneumonia (Animal)

Definition

Contagious bovine pleuropneumonia (CBPP) is an infectious and contagious respiratory disease of cattle and water buffalo caused by *Mycoplasma mycoides* subsp. *mycoides* (Mmm) with a major impact on livestock production and a potential for rapid spread (WOAH, 2024a).

Reference

WOAH. (2024a). Manual of Diagnostic Tests and Vaccines for Terrestrial Animals, 13th edition. World Organisation for Animal Health (WOAH). https://www.woah.org/fileadmin/Home/eng/Health_standards/tahm/3.04.08_CBPP.pdf Accessed 1 January 2025.

Annotations

Synonyms

Pleuropneumonie contagieuse bovine (fr), Peripneumonía contagiosa bovina (es). peripulmonite contagiosa dei bovini (Italian). Lung sickness or lung plague, Lungers (Africa)

Additional scientific description

Contagious bovine pleuropneumonia (CBPP) is a prominent cattle disease in Africa. With a mortality rate of up to 50%, it causes significant economic losses (WOAH, no date). CBPP is preventable through control measures, including vaccination. Most countries maintain a list of approved veterinary vaccines for use. For specific disease control recommendations, please contact the relevant national veterinary authorities.

CBPP was known in Europe as early as the 16th century. It was spread throughout the world by increased international trade in live cattle in the second half of the 19th century. Stamping out policy eradicated the disease from many countries; however, it currently persists in sub-Saharan Africa. The main problems for control or eradication are the frequent occurrence of subacute or unapparent infections and the persistence of chronic carriers after the clinical phase. Because it is highly contagious with a mortality rate of up to 50%, it causes significant economic losses. CBPP is a prominent cattle disease in Africa (WOAH, no date).

Typically, when first introduced into a CBPP-free herd, CBPP is severe and mortality relatively high. Transmission of the disease occurs through direct contact between an infected and a susceptible animal which becomes infected by inhaling droplets disseminated by coughing. Since some animals can carry the disease without showing signs of illness, controlling the spread is more difficult (WOAH, no date).

A small proportion of cattle may die rapidly without showing any clinical signs other than fever. However, because the incubation period can be as long as six months, the clinical signs may become apparent only several weeks after the contact. The disease can therefore become established in a herd before it is noticed, and tracing back to the origin can be difficult.

The hyperacute form, involving up to 10 percent of infected animals, may be observed at the onset of an outbreak. Death is sudden and is often without any other signs.

The acute form is observed in approximately 20 percent of diseased animals. The course is usually from five to seven days. The earliest signs are a sudden onset of fever to 40°C or more and, in milking cows, a drop in milk yield. Sick cattle tend to isolate themselves from the herd and may stop eating. A typical respiratory disease develops; breathing is laboured and obviously painful. Abdominal breathing with a respiratory rate of 50 to 55 breaths/minute may be seen and cattle may “grunt” when breathing out. Some animals develop a shallow, dry and painful cough, particularly noticeable on exercise. Application of pressure between the ribs is painful and resented by affected cattle, which sometimes react violently. On percussion, the ventral part of the chest sounds dull owing to the presence of fluid in the chest cavity. Acutely affected cattle stand with head and neck extended and forelegs spread apart (FAO, 1997 see Plate 1), with dilated nostrils and mouth open panting for air. There may be nasal

Preliminary – Corrections Pending

discharge, sometimes streaked with blood, and frothy saliva accumulates around the mouth. Some animals develop swellings of the throat and dewlap. Pregnant cows and heifers may abort, and diarrhoea has been recorded.

The subacute form occurs most frequently in about 40 to 50 percent of the animals affected. The symptoms resemble those of the acute form but are less severe and the fever is intermittent. This form usually becomes chronic.

At necropsy, the thoracic cavity may contain a lot of clear yellow or turbid fluid, and the diseased lung (largely unilateral, affecting only one lung) is enlarged, solid and covered by thick deposits of fibrin (FAO, 1997 see Plates 2). On a section of the lung, the typical marble-like appearance is evident because of the widened interlobular septa and subpleural tissue that encloses grey, yellow, or red consolidated lung lobules (FAO, 1997 see Plate 7 and 8).

The chronic form is a natural evolution of both acute and subacute forms but in some animals, it may develop directly. The clinical signs regress but cattle can still have intermittent fever, together with loss of both appetite and weight. In addition to the presence of lung adherence on the ribs (FAO, 1997 see Plate 5 and 6), areas of dead lung tissue become surrounded by a capsule of fibrous connective tissue. This structure is called a sequestrum (FAO, 1997 see Plate 9). Sequestra of different diameters can be detected in the same lung.

Calves in the first six months of life more often show lameness from swollen, hot, painful limb joints (FAO, 1997).

CBPP is one of the World Organisation for Animal Health (WOAH) listed diseases (WOAH, 2024b).

Humans are not known to be susceptible to CBPP, so there is no public health risk. (WOAH, 2024a; no date).

Metrics and numeric limits

CBPP is one of the World Organisation for Animal Health (WOAH) listed diseases (WOAH, 2024b). Reports are available on organisations such as the World Organisation for Animal Health map of CSF official status (WOAH) website (WOAH, 2024c)

Key relevant UN convention / multilateral treaty

WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) (WTO, 1994). https://www.wto.org/english/res_e/booksp_e/agrmntseries4_sps_e.pdf Accessed 1 January 2025.

United Nations. 2023. UN Recommendations on the Transport of Dangerous Goods - UN Model Regulations Model Regulations. https://unece.org/transport/dangerous-goods/un-model-regulations-rev-23 Accessed 1 January 2025.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Contamination may be caused by the introduction of the bacterium to a susceptible flock lack of biosecurity, and presence of vectors (FAO, 2017). CBPP may spread through cattle movements (e.g. transhumance or insecurity when displaced people bring their cattle when they move (or move back).

Impacts: death of infected animals, spread of infection, trade ban (FAO, 2017). Although the mortality rate is generally low, economic losses result from loss of condition, decreased milk production, abortions, infertility and damaged hides.

Multi-hazard Context: Not Applicable.

Monitoring: The section and the table below offer an overview of monitoring for contagious bovine pleuropneumonia. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Ministry of Agriculture, Ministry of Livestock; FAO Reference Centres, WOAH Reference Centres.
How is the Hazard Observed/Monitored/Forecast?	Through its global early warning system, FAO has been supporting Members with risk monitoring, assessment and forecasting for animal health threats to enhance preparedness and response to animal health threats: • The Global Animal Disease Information System, EMPRES-i+, plays a crucial role in supporting countries with early warning and early detection of animal disease outbreaks. By providing a comprehensive platform for real-time disease tracking, EMPRES-i+, enables monitoring and analysis of animal health threats effectively, collaborating closely with countries and regions on disease information sharing. This supports the dissemination of risk assessments and alerts for evidence-based decision-making. • FAO develops and maintains decision support tools that

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	provide risk maps of existing and predicted risks of animal disease emergence, as well as other threats to the agri-food chain. • Additionally, FAO collaborates closely with international organizations like WHO and WOAH to verify disease information through integrated mechanisms such as the Epidemic Intelligence from Open Sources (EIOS), the Global Early Warning System (GLEWS+), and the World Animal Health Information System (WAHIS) for WOAH-listed diseases. These collaborations allow for the dissemination of early warning alerts and risk assessments to Members, to enable timely responses to potential outbreaks. FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

Risk Management: The main problems for control or eradication are the frequent occurrence of subacute or unapparent infections and the persistence of chronic carriers after the clinical phase. In most continents, control strategies are based on the early detection of outbreaks, control of animal movements and a stamping-out policy. This has successfully eliminated the disease from North America and Europe. In Africa, control of the disease is currently based mainly on vaccination campaigns. However, it remains important that effective surveillance of the disease through slaughterhouse inspection is an efficient method of detecting clinical cases. Treatment of affected animals with antibiotics can result in healthy-looking animals that are still infected and able to spread the disease, so it is not recommended. Vaccination with an attenuated strain of the bacteria is used to reduce the level of infection but access to vaccines in remote areas remains complex (WOAH, no date).

In summary proving vaccination programmes, vector control, movement control and farm biosecurity are all critical to risk management of CBPP cases and outbreaks (FAO, 2017).

References

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Coordinating agency or organisation

Food and Agriculture Organization of the United Nations (FAO) and World Organization for Animal Health (WOAH).

Preliminary – Corrections Pending

BI0305 / BIOLOGICAL / Infectious Diseases

Contagious Caprine Pleuropneumonia (CCPP) (Animal)

Definition

Contagious caprine pleuropneumonia (CCPP) is a disease affecting goats and some wild ruminant species, caused by *Mycoplasma capricolum subsp. capripneumoniae* (Mccp). In goats, it is manifested by anorexia, fever and respiratory signs such as dyspnoea, polypnea, cough and nasal discharges. The acute and subacute disease is characterised by unilateral serofibrinous pleuropneumonia with severe pleural effusion. (Adapted from WOAH, 2021).

Reference

WOAH. (2021). Manual of Diagnostic Tests and Vaccines for Terrestrial Animals, 13th edition. World Organisation for Animal Health (WOAH). https://www.woah.org/fileadmin/Home/eng/Health_standards/tahm/3.08.04_CCPP.pdf Accessed 1 January 2025.

Annotations

Synonyms

Pleuropneumonie contagieuse caprine (fr), Perineumonía contagiosa caprina (es)

Additional scientific description

Contagious caprine pleuropneumonia (CCPP) is one of the most severe diseases of goats (Spickler, 2015). The disease caused by Mccp is readily contagious and fatal to susceptible goats of all ages and both sexes, rarely affects sheep and does not affect cattle (WOAH, 2021)

CCPP is a disease affecting goats and some wild ruminant species caused by *Mycoplasma capricolum* subsp. *capripneumoniae* (Mccp) (WOAH, 2021). This disease, which affects the respiratory tract, is extremely contagious and frequently fatal; in some naive flocks, the morbidity and mortality rates may reach 100% (Spickler, 2015). CCPP affects goats in more than 40 countries of the world thereby posing a serious threat to goat farming around the globe (Yatoo et al., 2019). In its acute form, it is manifested by anorexia and respiratory symptoms (coughing, nasal discharge, dyspnoea, polypnoea) and by the presence of exudative pleurisy and pneumonia. Some animals develop sub-acute forms with very limited and hardly detectable symptoms. The transmission of CCPP occurs by direct contact between infected and healthy animals (OIE, 2009). Typical lesions of CCPP are an accumulation of pleural fluid, unilateral hepatisation, adhesions, pleurisy and pleuropneumonia (Samiullah, 2013). Clinical signs of CCPP are very often confused with other causes, Pasteurellosis, peste des petits Ruminants (OIE, 2018). In the field, the control of CCPP is very often based on antibiotic treatment (WOAH, 2021). Diagnosis is carried out by clinical and necropsy observations that should be confirmed by laboratory tests (OIE, 2018). Definitive CCPP diagnosis can be difficult, as the detection of the causative agent by culture is very difficult and PCR is the preferred diagnostic to detect Mccp DNA in suspicious samples due to challenges in culturing the pathogen (Spickler, 2015).

The disease was first described in 1873 in Algeria. Shortly after, in 1881, the disease was introduced to South Africa by a shipment of Angora goats. The disease was eradicated using a policy of slaughtering the infected goats coupled with a traditional vaccination procedure for the in-contact goats. This organism was first isolated and shown to cause CCPP in Kenya, it has subsequently been isolated in Chad, Eritrea, Ethiopia, Niger, Oman, Sudan, Tanzania, Tunisia, Turkey, Uganda, the United Arab Emirates, and more recently in Mauritius, China Tajikistan and Saudi Arabia. CCPP was first reported in mainland Europe in 2004, when outbreaks were confirmed in the Thrace region of Turkey, with losses of up to 25% of kids and adults in some herds. However, the exact distribution of

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the disease is not known, and it may be much more widespread than the zone represented by the countries where Mccp has been isolated, as CCPP is often confused with other respiratory infections and also because the isolation of the causative organism is difficult (WOAH, 2021).

In CCPP outbreaks in mixed goat and sheep herds, sheep may also be infected, as verified by isolation of Mccp or detection of antibodies from clinically affected sheep. Mccp has also been isolated from healthy sheep and the role of sheep as a reservoir for the disease has to be considered. CCPP was first confirmed in wild ruminants kept in a wildlife preservation reserve in Qatar. The disease affected wild goats, Nubian Ibex, Laristan mouflon and Gerenuk with significant morbidity and mortality in these species. It has also been reported in gazelles in the United Arab Emirates. There is growing evidence that a number of wild ruminant species are susceptible, such as the Tibetan antelope and Arabian oryx. In sand gazelles, the mortality rate reached up to 70% (WOAH, 2021)

CCPP vaccines exist and are efficient. They include an Mccp purified and inactivated antigen adjuvanted with saponin (WOAH, 2021). CCPP can be controlled by the application of treatment during the outbreak, restricting animal movements, slaughtering infected animals and vaccination (Thiacourt et al., 1996). Most countries maintain a list of approved veterinary vaccines for use. For specific regulations, consult the country's veterinary authorities.

There is no evidence that humans are infected by Mccp (Spickler, 2015). The disease is included in the World Organisation for Animal Health (WOAH) list of notifiable diseases (WOAH, 2024). CCPP-free countries may pose trade restrictions on domestic and wild goats from countries considered infected with CCPP (WOAH, 2024).

Metrics and numeric limits

The disease is included in the World Organisation for Animal Health (WOAH) list of notifiable diseases (WOAH, 2024).

Key relevant UN convention / multilateral treaty

WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) (WTO, 1994). https://www.wto.org/english/res_e/booksp_e/agrmntseries4_sps_e.pdf Accessed 1 January 2025.

United Nations. 2023. UN Recommendations on the Transport of Dangerous Goods - UN Model Regulations Model Regulations. https://unece.org/transport/dangerous-goods/un-model-regulations-rev-23 Accessed 1 January 2025.

Examples of drivers, impacts, and risk management

Hazard Drivers: Contamination may be caused by the introduction of this bacterium to a susceptible flock, lack of biosecurity, and presence of vectors (FAO, 2017). CBPP may spread when displaced people bring their cattle when they move (or move back).

Impacts: death of infected animals, spread of infection, trade ban (FAO, 2017). Although the mortality rate is generally low, economic losses result from loss of condition, decreased milk production, abortions, infertility and damaged hides.

CCPP is considered one of the most severe and highly infectious diseases in goats. It results in heavy economic losses to countries involved in goat farming especially in Africa, Asia and the Middle East. The disease is one of the mycoplasmal infections resulting in significant losses in almost 40 countries, and morbidity and mortality can be as high as 100%, especially in exotic breeds. In naive and native herds, 100% morbidity and 80% mortality have been noted. It is estimated that the total yearly cost of CCPP is about US$507 million in endemic areas thus involving major economic losses. Economic losses are both by morbidity, mortality and decline or loss of production performance in addition to costs involved in prevention, control and treatment. Morbidity causes constraints in livestock management, overburdens with costs of treatment, and imposes restrictions on trade or transport. Mortality causes direct loss due to the death of the valuable animals. Diseased animals are usually culled in developed countries, which is not possible in under-developed and developing countries like India. Loss of production performance is severe (Yatoo et al., 2019).

As an example, the disease causes huge economic losses to Changpas, native inhabitants of Changthang, Ladakh, India who are traditional Pashmina farmers and are directly dependent (90-100%) on the traditional and nationally important venture-Pashmina farming and contribute 80% (45-50 tons) to national output (60 tons) of Pashmina. A loss of around 30% in Pashmina yield in CCPP-affected goats and a benefit-cost ratio of 0.79 in untreated animals against 8.76 in treated animals has been reported (Yatoo et al. 2019).

Multi-hazard Context: Not Applicable.

Monitoring: The section and the table below offer an overview of monitoring for contagious caprine pleuropneumonia. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Ministry of Agriculture, Ministry of Livestock; FAO Reference Centres, WOAH Reference Centres,
How is the Hazard Observed/Monitored/Forecast?	Through its global early warning system, FAO has been supporting Members with risk monitoring, assessment and forecasting for animal health threats to enhance preparedness and response to animal health threats:

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	• The Global Animal Disease Information System, EMPRES-i+, plays a crucial role in supporting countries with early warning and early detection of animal disease outbreaks. By providing a comprehensive platform for real-time disease tracking, EMPRES-i+, enables monitoring and analysis of animal health threats effectively, collaborating closely with countries and regions on disease information sharing. This supports the dissemination of risk assessments and alerts for evidence-based decision-making. • FAO develops and maintains decision support tools that provide risk maps of existing and predicted risks of animal disease emergence, as well as other threats to the agri-food chain. • Additionally, FAO collaborates closely with international organizations like WHO and WOAH to verify disease information through integrated mechanisms such as the Epidemic Intelligence from Open Sources (EIOS), the Global Early Warning System (GLEWS+), and the World Animal Health Information System (WAHIS) for WOAH-listed diseases. These collaborations allow for the dissemination of early warning alerts and risk assessments to Members, to enable timely responses to potential outbreaks. FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

Risk Management: CCPP risk management is via vaccination programmes, vector control, movement control and farm biosecurity (FAO, 2017; Samiullah, 2013).

References

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Coordinating agency or organisation

Food and Agriculture Organization of the United Nations (FAO) and World Organization for Animal Health (WOAH).

Preliminary – Corrections Pending

BI0306 / BIOLOGICAL / Infectious Diseases

Foot-and-mouth disease (Animal)

Definition

Foot-and-mouth disease is caused by a virus of the family *Picornaviridae*, genus *Aphthovirus*. It is a highly contagious and economically important disease of cloven-hoofed domestic animals (cattle, buffaloes, pigs, sheep, goats) and wild animals (adapted from FAO no date; WOAH, no date).

Reference

FAO, no date. Foot-and-mouth disease. https://www.fao.org/animal-health/animal-diseases/foot-and-mouth-disease/en. Accessed 28 May 2025.

WOAH, no date. Foot and mouth disease (FMD). World Organisation for Animal Health (WOAH). https://www.woah.org/en/disease/foot-and-mouth-disease/ Accessed 28 May 2025.

Annotations

Synonyms

FMD. Hoof and mouth disease, Fièvre aphteuse (fr), Fiebre aftosa (es).

Additional scientific description

Foot-and-mouth disease (FMD) is a devastating animal disease affecting all cloven-hoofed animals, both domestic and wild species. The virus is among the most infectious in veterinary medicine, prompting major concern among livestock producers FMD can be controlled by vaccination with a matching vaccine; there are seven immunologically distinct serotypes: A, O, C, SAT1, SAT2, SAT3, and Asia1 which do not confer cross immunity (WOAH, no date). Each country typically maintains a list of registered veterinary vaccines approved for use. For specific regulations, consult the country's veterinary authorities. (WOAH, no date).

The most common means of transmission for the FMD virus is by direct contact between FMD-infected and healthy animals. All secretions and excretions of clinically ill (sick) animals are extremely infectious. Therefore, significant risk factors for transmission include shared grazing or watering points and movement and mixing of different groups of animals. Cattle, buffaloes, sheep and goats are especially vulnerable to infection transmitted by aerosols (air-borne particles carrying the virus), which is the main source of infection in animals living in close quarters (EU, no date; WOAH, no date).

In rare cases, FMD infection has appeared to be transmitted by air over long distances, but this has only ever occurred under particular conditions - where large numbers of infected pigs generate a plume of virus that is conveyed downwind to susceptible cattle or sheep.

FMD is characterized by depression, lameness, excessive salivation, anorexia, reduced milk yield and fertility. Clinical examination reveals the formation of vesicles (blisters) in and around the oral cavity, feet and on the teats (FAO, no date; WOAH, 2022).

The morbidity rate (number of animals clinically affected) may approach 100% in susceptible cattle populations. FMD is estimated to circulate in 77% of the global livestock population, in Africa, the Middle East and Asia, as well as in a limited area of South America. Countries that are currently FMD-free remain under constant threat of an incursion (WOAH, no date).

FMD is not transmissible to people so it does not pose a risk to human health.

However, FMD has an important impact on livelihoods and economic development as it is a significant impediment to international trade and movement of susceptible livestock and animal products. FMD-free countries will not accept imports of animals or products from countries that are not free of the disease.

For FMD outbreak response, implement biosecurity measures and movement controls. Emergency (ring) vaccination may be employed. Stamping out may be applied in previously free countries that intend to regain this status. Livestock keepers should

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regularly check animals of susceptible species and report any suspect cases to a veterinarian or veterinarian service.

Metrics and numeric limits

FMD is a WOAH-listed disease and must be reported to the Organisation, as indicated in the Terrestrial Animal Health Code. World Animal Health Information System WAHIS is the global animal health reference database of the World Organisation for Animal Health (WOAH). WAHIS data reflects the validated information since 2005 reported by the Veterinary Services from Member and non-Member Countries and Territories on terrestrial and aquatic Listed diseases in domestic animals and wildlife, as well as on emerging diseases and zoonoses. WAHIS includes interactive mapping tools and dashboards to support data consultation, visualization and extraction of officially validated animal health data (WOAH, no date).

Key relevant UN convention / multilateral treaty

WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) (WTO, 1994). https://www.wto.org/english/res_e/booksp_e/agrmntseries4_sps_e.pdf

United Nations. 2023. UN Recommendations on the Transport of Dangerous Goods - UN Model Regulations. https://unece.org/transport/dangerous-goods/un-model-regulations-rev-23

UNODA, 1972. Convention on the prohibition of the development, production and stockpiling of bacteriological (biological) and toxin weapons and on their Destruction. https://legal.un.org/avl/ha/cpdpsbbtwd/cpdpsbbtwd.html

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: FMD spreads easily in areas experiencing civil conflicts or disasters resulting in the displacement of animals together with people. In such areas, vaccination to raise herd immunity is difficult to perform, and movement (displacement) of susceptible animals spreads the disease. Lack of biosecurity, swill feeding, unregulated transport and trade of susceptible animals (cattle, buffaloes, pigs, sheep, goats and other cloven-hoofed ruminants) and uncooked animal products (FAO, no date) are also drivers.

Impacts: spread of infection, trade ban, compromise Sustainable Development Goals. It has a huge detrimental impact on livelihoods, food security and national economies through loss of milk yields, lowered fertility and reduced or prohibited access to markets (FAO, no date; WOAH, no date).

Low-income and lower-middle-income countries bear 75% of the global costs of FMD prevention and control and Africa and Eurasia are the regions contributing the most to that cost, accounting for 50% and 33% of the global expenditure of FMD control and prevention, respectively (WOAH, no date). Thus, it threatens the livelihood of millions of poor livestock keepers and food security in the FMD endemic regions. FMD-infected countries are excluded from international trade of live susceptible animals, their meat and meat products (FAO, no date). Although FMD had been largely controlled in developed nations, in 2001, an outbreak in the United Kingdom spread to the Netherlands, with smaller outbreaks in France and Ireland, before being brought under control by widespread culling. The experience left its mark on the psyche of many of the farmers who lived through the tragedy: the United Kingdom alone suffered economic losses of more than USD 12 billion, and some 6.5 million sheep, cattle and pigs were slaughtered to halt the spread of the disease (FAO, no date).

Multi-hazard Context: Not Applicable.

Monitoring: The section and the table below offer an overview of monitoring for foot and mouth disease. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	FAO Reference Centres, WOAH Reference Centres
How is the Hazard Observed/Monitored/Forecast?	EuFMD FMD quarterly reports https://www.fao.org/eufmd/resources/reports/quarterlyreport/en/ FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

Risk Management: vaccination with a matching vaccine (prevention), movement control, improvement of farm biosecurity, and depopulation of infected herds may be applied in some situations (WOAH, no date).

The Food and Agriculture Organization of the United Nations (FAO) and the World Organisation for Animal Health (WOAH) are working together for global control of FMD. In partnership with the FAO-based European Commission for the Control of Foot-and-Mouth Disease (EuFMD), the FAO has developed the Progressive Control Pathway for Foot-and-Mouth Disease control (PCP-FMD), which guides endemic countries through a series of incremental steps to successfully control the disease (FAO, no date).

Early detection and rapid response are key to minimizing the impact of FMD introduction. Therefore, it is important to raise the

Preliminary – Corrections Pending

awareness of livestock keepers about the disease and what signs to look out for, to stress the importance of regularly checking susceptible animals and reporting any suspicious signs to a veterinarian or veterinarian service.

References

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WOAH, no date. WAHIS: World Animal Health Information System World Organisation for Animal Health (WOAH). https://wahis.woah.org/#/home Accessed 28 May 2025.

Coordinating agency or organisation

Food and Agriculture Organization of the United Nations (FAO) and World Organization for Animal Health (WOAH).

Preliminary – Corrections Pending

BI0307 / BIOLOGICAL / Infectious Diseases

Lumpy Skin Disease (Animal)

Definition

Lumpy skin disease is a vector-borne pox disease of domestic cattle and Asian water buffalo and is characterised by the appearance of skin nodules on all body surfaces including the udder (FAO, 2017).

Reference

FAO, 2017. Lumpy Skin Disease: A field manual for veterinarians. Food and Agriculture Organization of the United Nations (FAO) Animal Production and Health Manual No. 20. https://openknowledge.fao.org/server/api/core/bitstreams/1c277d5a-b2eb-42f3-a32a-9c71fde089f0/content . Accessed 28 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Dermatose nodulaire contagieuse (fr), Dermatosis nodular contagiosa (es)

Additional scientific description

Lumpy skin disease (LSD) is caused by the lumpy skin disease virus (LSDV), a member of the genus *Capripoxvirus* (CaPV) within the family *Poxviridae*, with significant morbidity in cattle that has dramatic effects on rural livelihoods (FAO, 2017). The LSDV shares the genus with sheep pox virus (SPPV) and goat pox virus (GTPV), which are closely related, but phylogenetically distinct. LSD is one of the World Organisation for Animal Health (WOAH) listed diseases (WOAH, 2024b).

LSD morbidity rate varies between 10 and 20% although it has been reported in some places to be as high as 45% with mortality rates of 1 to 5% considered usual (WOAH, 2022).

LSD spreads mainly through mechanical transmission by arthropod vectors. In addition to vectors, transmission may occur through consumption of contaminated feed or water, direct contact, natural mating or artificial insemination (FAO, 2017).

Although traditionally limited to sub-Saharan Africa, LSD has spread rapidly to new territories since 2015 including the Middle East and Turkey, and most of the Balkan countries, the Caucasus and the Russian Federation, causing substantial economic losses and a serious threat to the food security. Further, in 2019, LSD was also reported in Bangladesh, China and India and in 2020 it reached Chinese Taipei (WOAH, no date a). LSD can rapidly spread across national borders and reach epidemic proportions, thus requiring regional cooperation in prevention, control and eradication (FAO, 2017).

LSD is preventable through control measures, including vaccination (Metwally et al., 2021). Large-scale vaccination is the most effective way to prevent and control the disease spread. Effective live attenuated vaccines are the most commonly used vaccines against LSD commercially available and the sooner they are used the less severe the economic impact of an outbreak is likely to be (FAO, 2017). Each country typically maintains a list of registered veterinary vaccines approved for use. For specific regulations, consult the country's veterinary authorities.

There is no evidence that LSDV can infect humans (FAO, 2017).

Metrics and numeric limits

LSD is a WOAH-listed disease and must be reported to the Organisation, as indicated in the Terrestrial Animal Health Code. World Animal Health Information System WAHIS is the global animal health reference database of the World Organisation for Animal Health (WOAH). WAHIS data reflects the validated information since 2005 reported by the Veterinary Services from Member and non-Member Countries and Territories on terrestrial and aquatic Listed diseases in domestic animals and wildlife, as well as on emerging diseases and zoonoses. WAHIS includes interactive mapping tools and dashboards to support data consultation, visualization and extraction of officially validated animal health data (WOAH, no date b).

Key relevant UN convention / multilateral treaty

WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) (WTO, 1994). https://www.wto.org/english/res_e/booksp_e/agrmntseries4_sps_e.pdf Accessed 1 January 2025.

United Nations. 2023. Recommendations on the Transport of Dangerous Goods - UN Model Regulations. https://unece.org/transport/dangerous-goods/un-model-regulations-rev-23 Accessed 1 January 2025.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: LSD easily spreads in areas experiencing storms, flooding, civil conflict, insecurity, displacement of people, and greater need to remain mobile, due to difficulties in maintaining high biosecurity. Other drivers include lack of biosecurity, and the presence of vectors (FAO, 2017).

Impacts: death of infected animals, spread of infection, trade ban (FAO, 2017). Although the mortality rate is generally low, economic losses result from loss of condition, decreased milk production, abortions, infertility and damaged hides.

Multi-hazard Context: LSDV is remarkably stable, surviving for long periods at ambient temperature, especially in dried scabs. LSDV is very resistant to inactivation, surviving in necrotic skin nodules for up to 33 days or longer, desiccated crusts for up to 35 days, and at least 18 days in air-dried hides. It can remain viable for long periods in the environment. The virus is susceptible to sunlight and detergents containing lipid solvents, but in dark environmental conditions, such as contaminated animal sheds, it can persist for many months (WOAH, 2022).

Monitoring: The section and the table below offer an overview of monitoring for lumpy skin disease. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	FAO Reference Centres, WOAH Reference Centres,
How is the Hazard Observed/Monitored/Forecast?	FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

Risk Management: vaccination programme, vector control, movement control, farm biosecurity (FAO, 2017).

The Food and Agriculture Organization of The United Nations (FAO) provides guidance on prevention measures (FAO, no date). It is difficult to stop cattle from being attacked by infected vectors (flies, etc.) once the infection is within an area. Risk behaviours increase the probability of infection being carried between locations. Large-scale vaccination is the most effective way to prevent and control the disease spread (FAO, 2017). The FAO guidance on preventative measures that can improve the level of protection of a herd from LSD and other infectious diseases includes the following (FAO, no date):

- ***Implement biosecurity measures:***
  - As livestock and vehicles can carry live vectors (flies, mosquitoes, etc.) between areas, avoid entry or opening of such vehicles within or close to livestock holdings unless disinfested with approved products.
  - Protect animals from insects (e.g. treatment with approved repellents, move animals to locations within the holding where fewer biting flies).
  - Change needles when treating animals.
- ***General measures to reduce the risk of LSD and other diseases:***
  - Disinfectant footbath at the entrance of the stable.
  - Disposable boot covers and suits for the visitors.
  - Disinfection and disinfestation of vehicles prior to and after movements.
  - Raise awareness at livestock keepers, field veterinarians and animal health workers levels and encourage reporting to the central veterinary authority.
- ***Avoid***:
  - Contacts between animals of different herds (e.g. on pasture).
  - Grazing areas where nuisance flies are very abundant.
  - Sharing animals, tools, vehicles, and personnel with other farms.

Awareness of the herd may be at risk. It is very important to check regularly all the animals and report to a veterinarian or veterinarian

Preliminary – Corrections Pending

service.

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WOAH, no date a. Lumpy Skin Disease. World Organisation for Animal Health (WOAH). https://www.woah.org/en/disease/lumpy-skin-disease/ Accessed 1 January 2025.

WOAH, no date b. WAHIS: World Animal Health Information System World Organisation for Animal Health (WOAH). https://wahis.woah.org/#/home Accessed 28 May 2025.

Coordinating agency or organisation

Food and Agriculture Organization of the United Nations (FAO) and World Organization for Animal Health (WOAH).

Preliminary – Corrections Pending

BI0308 / BIOLOGICAL / Infectious Diseases

zoonosis

Newcastle Disease (Animal)

Definition

Newcastle Disease (ND) is a highly contagious and often severe disease found worldwide that affects birds caused by virulent strains of avian paramyxovirus type 1 (WOAH, no date).

Reference

WOAH, no date. Newcastle Disease. World Organisation for Animal Health (WOAH). https://www.woah.org/en/disease/newcastle-disease/ Accessed 27 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Maladie de Newcastle, Enfermedad de Newcastle, Ranikhet disease, Avian paramyxovirus Type 1-Velogenic Newcastle disease virus.

Additional scientific description

Human
Newcastle disease virus (NDV) is capable of infecting humans, causing a mild transient conjunctivitis which is self-limiting with no permanent effect, however, no human-to-human transmission has been reported. Conjunctival infection usually occurs due to physical introduction into the eye by operatives manipulating vaccines prior to vaccination of birds, usually with a finger or by splashing vaccine (WOAH, no date).
Animal
Newcastle Disease (ND) is a highly impactful poultry disease that affects livelihoods and food security and has zoonotic potential (WOAH, 2024a; WOAH, 2024b; WOAH, 2024c). Outbreaks can severely impact village chickens in developing countries, where poultry serves as a vital protein source and ND remains endemic (FAO, 2004). However, it is preventable through control measures, including vaccination. A wide range of ND vaccines is available worldwide, including both live and inactivated (killed) vaccines. Most countries maintain a list of approved veterinary vaccines for use. For specific regulations, consult the country's veterinary authorities. Newcastle disease (ND) is one of the most important diseases in poultry worldwide and is endemic in many parts of the world. It causes devastating losses to the poultry industry, whilst impacting food security in many countries. It is caused by the Newcastle disease virus (NDV), which belongs to the avian *orthoavulavirus type 1* (AOAV-1) serotype and is a member of the *Paramyxoviridae* family. Although chickens appear to be the most susceptible domestic species to NDV, the virus is capable of infecting a wide range of avian species, such as ducks and other species can act as reservoir hosts, such as Columbiformes (including pigeons and doves) which may be significant in the spread and transmission of disease. NDV is capable of infecting humans, causing a mild transient conjunctivitis which is self-limiting with no permanent effect, however, no human-to-human transmission has been reported. Conjunctival infection usually occurs due to physical introduction into the eye by operatives manipulating vaccines prior to vaccination of birds, usually with a finger or by splashing the vaccine. The disease is exhibited in five forms; highly virulent infection with haemorrhagic lesions in the intestinal tract; neurotropic causing high mortality following nervous signs; respiratory and sometimes nervous signs with low to moderate mortality; mild respiratory and/or unapparent enteric infection and avirulent asymptomatic. The mode of transmission from bird to bird is dependent on the tropism of the virus, with birds that show respiratory disease, shedding the virus in droplets and aerosolised mucus which may be inhaled by susceptible birds. Viruses restricted to replication in the gastrointestinal tract may be transferred by ingestion of contaminated faeces either directly or in contaminated food or water or by the inhalation of small infective particles produced in dried faeces. The clinical signs vary from loss of appetite, coughing, gasping, nasal discharge, watery eyes, bright green diarrhoea and nervous signs such as paralysis and convulsions. Combs and wattles may look swollen, enlarged and discoloured (purple or blue), reduced egg production with the few eggs that produced being soft-shelled and malformed. Humans have a central role in the spread of NDV, mainly through the movement of live birds, fomites, personnel and poultry. It is important to note that NDV is capable of infecting humans, causing a mild transient conjunctivitis which is self-limiting with no permanent effect, however, no human-to-human transmission has been reported. Conjunctival infection usually occurs due to physical introduction into the eye by operatives manipulating vaccines prior to vaccination of birds, usually with a finger or by splashing the vaccine.

For these reasons, control and eradication of the disease presents significant challenges to the poultry industry worldwide, and therefore the use of vaccination has been applied for many decades as an important control tool.

The commercial vaccines can be broadly divided into live attenuated vaccines and inactivated vaccines. Live attenuated vaccines vary in their relative tropism for respiratory, enteric and nervous systems, they are controlled however to prevent adverse clinical side effects. There are many aspects of vaccine specification that should be considered in the context of the epidemiological situation where it will be used. A detailed account of all aspects of ND vaccines, including their production and use has been published (Allan, Lancaster and Toth 1978). The fundamental considerations should be for safety, quality and efficacy.

Metrics and numeric limits

N/A

Key relevant UN convention / multilateral treaty

WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) (WTO, 1994). https://www.wto.org/english/res_e/booksp_e/agrmntseries4_sps_e.pdf Accessed 1 January 2025.

United Nations, 2023. UN Recommendations on the Transport of Dangerous Goods - UN Model Regulations. https://unece.org/transport/dangerous-goods/un-model-regulations-rev-23 Accessed 1 January 2025.

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Human
Hazard Drivers: Poultry crews and laboratory workers would be at the greatest risk for potential exposure to the virus during their work (CFSPH, 2008). **Impacts**: Not Applicable
Animal
Drivers: introduction of virus to a susceptible flock, via poultry trade-related activities or wild birds. **Impacts:** high mortality in poultry with sudden death of birds, trade ban, livelihoods and food security implications, gender (women and children are often the ones caring for poultry).

Multi-hazard Context: Not Applicable

Monitoring: The section and the table below offer an overview of monitoring for Newcastle disease. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Ministry of Agriculture, Ministry of Livestock, Ministry of Health, FAO Reference Centres, WOAH Reference Centres, WHO
How is the Hazard Observed/Monitored/Forecast?	Through its global early warning system, FAO has been supporting Members with risk monitoring, assessment and forecasting for animal health threats to enhance preparedness and response to animal health threats: • The Global Animal Disease Information System, EMPRES-i+, plays a crucial role in supporting countries with early warning and early detection of animal disease outbreaks. By providing a comprehensive platform for real-time disease tracking, EMPRES-i+, enables monitoring and analysis of animal health threats effectively, collaborating closely with countries and regions on disease information sharing. This supports the dissemination of risk assessments and alerts for evidence-based decision-making. • FAO develops and maintains decision support tools that provide risk maps of existing and predicted risks of animal disease emergence, as well as other threats to the agri-food chain. • Additionally, FAO collaborates closely with international organizations like WHO and WOAH to verify disease information through integrated mechanisms such as the Epidemic Intelligence from Open Sources (EIOS), the Global Early Warning System (GLEWS+), and the World Animal Health Information System (WAHIS) for WOAH-listed diseases. These collaborations allow for the dissemination of early warning alerts and risk assessments to Members, to enable timely responses to potential outbreaks. FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

Preliminary – Corrections Pending

Risk Management

Human
Risk Management: CFSAPH (2008) provides guidance on Newcastle disease and CDC (2024) provides guidance on How to stay healthy around backyard poultry.
Animal
Risk Management: farm and market biosecurity, vaccination programme (prevention), movement control, depopulation, tracing back/forward.

References

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Coordinating agency or organisation

Food and Agriculture Organization of the United Nations (FAO) and World Organization for Animal Health (WOAH).

Preliminary – Corrections Pending

BI0309 / BIOLOGICAL / Infectious Diseases

zoonosis

New World Screwworm (NWS) (Human and Animal)

Definition

The New World screwworm (NWS), *Cochliomyia hominivorax* (Coquerel), is an obligate parasite of mammals, including humans, during their larval stages. Larvae feeding on the skin and underlying tissues of the host cause a condition known as wound or traumatic myiasis, which can be fatal (adapted from PAHO, no date and WOAH, no date).

Reference

PAHO, no date. Miasis por larvas de *Cochliomyia hominivorax* Pan American Health Organization (PAHO) https://www.paho.org/es/temas/miasis-por-larvas-cochliomyia-hominivorax Accessed 27 May 2025.

WOAH, no date. New World Screwworm (*Cochliomyia hominivorax*) https://www.woah.org/en/disease/new-world-screwworm-cochliomyia-hominivorax/ Accessed 27 May 2025.

Annotations

Synonyms

Myiase à Lucilie bouchère (*Cochliomyia hominivorax*) (fr), Miasis por *Cochliomyia hominivorax*, gusano barrenador del ganado (es)

Additional scientific description

The New World screwworm, *Cochliomyia hominivorax Cocquerel*, is a blowfly that is an obligate parasite of warm-blooded animals in tropical and subtropical regions of South America and the Caribbean. Females seek animals or humans and lay their eggs on the skin, often near open wounds (PAHO, no date: WOAH, no date). Larvae feed on the animal's living tissues, enlarging the wound, which can cause death if not treated. The period between oviposition at a wound site and the expression of disease due to burrowing larvae can be as short as one to two days. After cessation of feeding, larvae leave the animal and pupate in the soil. The life cycle takes approximately three weeks. Infestation of tissue by fly larvae is known as 'myiasis'.

Human
NWS infestations in humans are rare but very painful. If you have an NWS infestation, you may see maggots (larvae) around or in an open wound. They could also be in your nose, eyes, or mouth. Tell your healthcare provider of any recent travel to Central or South America, or the Caribbean. Symptoms can also include • Unexplained skin lesions (wounds or sores) that do not heal. • Skin wounds or sores that worsen over time. • Painful skin wounds or sores. • Bleeding from open sores. • Feeling larvae movement within a skin wound or sore, nose, mouth, or eyes. • Seeing maggots around or in open sores. • A foul-smelling odour from the site of the infestation. Secondary bacterial infections sometimes occur and may cause fever or chills (CDC, 2024).

Preliminary – Corrections Pending

Animal

In 1988, the parasite spread from the Americas to Libya; it was identified by Libyan veterinarians in the northwest part of the country. The mode of introduction and the country from which the pest came remain unknown. Positive taxonomic identification of the pest was made by British scientists, and the Food and Agriculture Organization of the United Nations (FAO) confirmed the presence of the new world screwworm myiasis disease in Libya in March 1989 (Lindquist & Abusowa, 1991). Many cases of screwworm myiasis have been documented in humans.

Economic losses due to screwworm infestation of livestock are significant. In 2005, it was estimated that in South America alone annual losses were approximately USD 3.6 billion (Scott et al., 2020). New World screwworm eradication programmes have eliminated this myiasis from Curacao, Puerto Rico, the Virgin Islands, the USA, Mexico and in Central America (Guatemala, Belize, El Salvador, Honduras, Nicaragua, Costa Rica), down to Panama on the southern part of the country where a buffer zone was established.

Since 2021, the New World screwworm fly has been making a dramatic comeback (reinfestation) in regions where it had been eradicated for over 30 years. All Central American countries and, more recently, Mexico have reported its reappearance. This resurgence poses a significant threat to livestock, wildlife, and public health. As of 2024, New World screwworm is found in all countries in Central America (Belize, Costa Rica, El Salvador, Guatemala, Honduras, México, Nicaragua, Panamá), three in Caribbean (Cuba, Dominican Republic, Jamaica) out of its13 sovereign states, and 10 out of 12 countries from South Americas (Argentina, Bolivia, Brazil, Colombia, Ecuador, Paraguay, Peru, Suriname, Uruguay, Venezuela; and suspected in Guyana).

The disease can quickly become debilitating or fatal if it affects the eyes, mouth, nasal or frontal sinuses, or ears (CFSPH, 2016). Clinical presentation of screwworms is always associated with a variety of pre-established wounds and should be considered in the event of any myiasis. Wounds may manifest draining or enlargement; signs of infestation with serosanguineous discharge are often accompanied by a distinctive odour. Animals with screwworm myiasis often display discomfort and appear unthrifty and depressed; separate from the group and may also manifest anorexia and reduced milk production. Morbidity, although variable in areas with high screwworm populations, may reach up to 100% in naval wounds of newborns. If untreated, animals may die within one to two weeks due to over-infestation, toxic shock and/or secondary bacterial infection.

Laboratory diagnosis is by identification of the parasites under the microscope. Field diagnosis of screwworm larvae, even with a microscope or magnifying glass, is difficult. Adult screwworms are rarely seen. They are also difficult to distinguish from other flies. Other techniques used mainly in research laboratories include cuticular hydrocarbon analysis, analysis of mitochondrial DNA, and random amplified polymorphic DNA polymerase chain reaction (RAPD-PCR) assays. Serology is not used (CFSPH, 2016).

Screwworm infestations can be treated in both endemic and non-endemic regions; euthanasia of the animal is not usually required. Although some wounds may be surgically excised, most are treated with a suitable larvicide and allowed to heal without closure. Treatment is usually repeated at intervals until the wound has healed. Removal of necrotic tissue may be necessary, and antibiotics may be given when secondary bacterial contamination is present. In non-endemic regions, the animal is quarantined until treatment is complete and the wound has healed. Treatment of the environment may also be necessary. Larvae that are removed from the wound must be placed in alcohol preservative or destroyed. If any larvae leave an infested wound and mature into adults, screwworms can become established in an area (CFSPH, 2016).

Metrics and numeric limits

N/A

Key relevant UN convention / multilateral treaty

United Nations. 2023. UN Recommendations on the Transport of Dangerous Goods - UN Model Regulations Model Regulations. https://unece.org/transport/dangerous-goods/un-model-regulations-rev-23 Accessed 1 January 2025.

WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) (WTO, 1994). https://www.wto.org/english/res_e/booksp_e/agrmntseries4_sps_e.pdf Accessed 1 January 2025.

International Health Regulations (2005), 3rd ed. (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard drivers and impacts

Human

Hazard Drivers: NWS is endemic in the American tropics and subtropics which includes the countries of South America, Cuba, Haiti, and the Dominican Republic. There have been recent cases in Central American countries for the first time in many years. People at higher risk include

- Those living in rural areas in regions or countries where NWS is endemic, and where livestock are raised.
- People who frequently work with livestock.
- Anyone with open sores or wounds, including from a recent surgery, as the flies will lay eggs on open sores.
- Vulnerable populations, including people who are immunocompromised, those at extremes of age, and people experiencing malnutrition.

Impacts: NWS larvae cause extensive damage by tearing into the host's tissue with sharp mouth hooks. The wound can become larger and deeper as more larvae hatch and feed on living tissue. As a result, NWS can cause serious damage to the animal or person it infects. Bacterial superinfection can also occur because of the NWS infestation (CDC, 2024).

Preliminary – Corrections Pending

Animal
Hazard Drivers: NSW fly may spread together with NWS-infected livestock or pets of displaced people when they move (or move back). The presence/introduction of screwworm fly (*Cochliomyia hominivorax*), and the introduction of infected livestock or pets are other drivers. **Impacts**: death of infected animals, spread of infection, trade ban.

Multi-hazard Context: Not Applicable

Monitoring: The section and the table below offer an overview of monitoring new world screwworm. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Ministry of Agriculture, Ministry of Livestock, Ministry of Health, FAO Reference Centres, WOAH Reference Centres
How is the Hazard Observed/Monitored/Forecast?	Through its global early warning system, FAO has been supporting Members with risk monitoring, assessment and forecasting for animal health threats to enhance preparedness and response to animal health threats: • The Global Animal Disease Information System, EMPRES-i+, plays a crucial role in supporting countries with early warning and early detection of animal disease outbreaks. By providing a comprehensive platform for real-time disease tracking, EMPRES-i+, enables monitoring and analysis of animal health threats effectively, collaborating closely with countries and regions on disease information sharing. This supports the dissemination of risk assessments and alerts for evidence-based decision-making. • FAO develops and maintains decision support tools that provide risk maps of existing and predicted risks of animal disease emergence, as well as other threats to the agri-food chain. • Additionally, FAO collaborates closely with international organizations like WHO and WOAH to verify disease information through integrated mechanisms such as the Epidemic Intelligence from Open Sources (EIOS), the Global Early Warning System (GLEWS+), and the World Animal Health Information System (WAHIS) for WOAH-listed diseases. These collaborations allow for the dissemination of early warning alerts and risk assessments to Members, to enable timely responses to potential outbreaks. FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

Risk Management

Human
Risk Management: Clinicians can diagnose NWS by finding fly larvae (maggots) in tissue. Identification of the genus or species involves comparing certain morphological structures on the larvae, including the anterior and posterior spiracles, mouthparts, cephalopharyngeal skeleton, and cuticular spines. Travel history can also be helpful for genus or species-level identification. The best way to prevent New World Screwworm (NWS) is to avoid exposure. Healthcare providers should • Be alert for NWS symptoms in people with a history of recent travel to regions where NWS is endemic. • Encourage patients to avoid spending time around livestock or where livestock are housed while in rural areas in NWS endemic regions. • Advise patients to clean and cover wounds, wear loose-fitting, long-sleeved shirts, pants and socks, and use Environmental Protection Agency (EPA)-registered insect repellents. • Advise patients to avoid sleeping outdoors and protect sleeping quarters with screens or bed nets, especially where people have wounds or active nasal or ocular discharges. Screening of hospital windows and doors is essential (CDC, 2024).
Animal
Risk Management: control programme using sterile insect technique (SIT), movement control, and improved biosecurity at farms. New World screwworm is a disease listed by the World Organisation for Animal Health (WOAH) in its Terrestrial Animal Health Code and must be reported to the WOAH (WOAH, 2024b). For control of screwworms, the implementation of voluntary and regulatory actions can prevent the introduction of screwworms to pest-free areas. Screwworms can enter non-endemic areas in infested animals or as adult flies. Vehicles that may contain adults or immature screwworms should be sprayed with insecticides. Imported animals (including pets) must be inspected for infestations and treated, before they are allowed to enter. As a precaution, wounds that do not appear to be infested may be treated with an insecticide. Animals may also be sprayed or dipped. Any infestations that become apparent after an animal enters the country must be treated promptly (CFSPH, 2016). To prevent the spread of screwworms beyond their present geographical distribution, strict observation of the requirements for international trade, as set out in the WOAH Terrestrial Animal Health Code, is necessary (WOAH, 2024a; 2024b). In endemic areas, animals must be inspected for screwworms every few days. Livestock can also be protected by regular spraying or dipping with insecticides, or by subcutaneous injections of ivermectin and related compounds. Insect growth regulators have also shown good results. Organophosphate insecticides are effective against newly hatched larvae, immature forms and adult flies. Other insecticides, such as carbamates and pyrethroids have also been used. Acaricide resistance can be an issue. In areas where screwworms are seasonal, breeding can be scheduled to avoid births when these flies are numerous. Indirect prevention of screwworm

Preliminary – Corrections Pending

infestation includes avoidance of wounding procedures at the times of year when screwworms are numerous; careful handling of livestock to minimise wounding; removal of sharp objects (e.g., wire strands) from livestock pens; and use of measures to reduce other wound-causing parasites, in particular ticks (e.g. by dipping and by insecticide impregnated ear-tags) (CFSPH, 2016).

Screwworms can be eradicated from a region by repeatedly releasing sterile male flies that mate with wild female screwworms to produce unfertilised eggs. Because it is usually impractical to separate irradiated male and female flies, both males and females are usually released. This technique, known as the sterile insect technique (SIT), leads to a reduction in screwworm numbers and eventually results in eradication. In addition, infested animals are treated, and their movements are controlled (CFSPH, 2016).

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Coordinating agency or organisation

Food and Agriculture Organization of the United Nations (FAO), World Health Organization (WHO) and World Organization for Animal Health (WOAH).

Preliminary – Corrections Pending

BI0310 / BIOLOGICAL / Infectious Diseases

Peste Des Petits Ruminants (Animal)

Definition

Peste des petits ruminants is a highly contagious and devastating disease of goats and sheep. The causative agent, Peste des petits ruminants virus is a member of the genus *Morbillivirus*, Family *Paramyxoviridae* and Order *Mononegavirales* (adapted from FAO, no date and WOAH, 2024a).

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WOAH, 2024a. Peste des petits ruminants. World Organisation for Animal Health (WOAH). https://www.woah.org/en/disease/peste-des-petits-ruminants/ Accessed 1 September 2024.

Annotations

Synonyms

N/A

Additional scientific description

PPR is a preventable disease by vaccine. The PPR vaccine provides a good example of solid immunity obtained with a live attenuated vaccine. PPR vaccination should be carried out according to the epidemiological situation of each area/country (Diallo & Singh, 2021). Usually, each country has a list of registered veterinary vaccines that are allowed to be used in the country. Contact the veterinary authorities of the country for more information.

Peste des Petits Ruminants (PPR) is a highly contagious animal disease affecting domestic and wild small ruminants. It is caused by a virus belonging to the genus *Morbillivirus*, family *Paramixoviridae*. Once newly introduced, the virus can infect up to 90% of a small ruminant flock, and the disease kills anywhere up to 70% of infected animals (FAO, no date).

PPR was first described in 1942 in Côte d'Ivoire, West Africa. Since then, the disease has spread to large regions of Africa, the Middle East, Asia and Europe. Today, more than 70 countries are affected or at high risk and many more are without an official PPR status. PPR-infected and at-risk countries are home to approximately 1.7 billion heads – around 80% – of the global population of sheep and goats (FAO, no date).

Transmission of PPR is mainly by aerosol or direct contact between animals living in close quarters and via fomites spreading infection via bedding, feed, pasture and water troughs (OIE, 2020).

PPR causes annual economic losses of up to USD 2.1 billion. Looking beyond this figure, 300 million families are at risk of losing their livelihoods, food security, and employment opportunities. Moreover, small ruminants and their products are internationally traded commodities, particularly in Africa and the Middle East. PPR considerably affects export earnings and creates supply shortages. The inability of families, communities, and institutions to anticipate, absorb, or recover from PPR can compromise national and regional development efforts, and reverse decades of progress (FAO, no date).

Until recently, this virus was named simply Peste des Petits Ruminants Virus (PPRV); the official name of this virus was changed in 2016 to small ruminant morbillivirus (SRM). However, it is still commonly known as PPRV by people working in the field. It is antigenically similar to the rinderpest virus, measles virus and canine distemper virus. It is transmitted by direct contact with diseased animals. PPR also occurs in some wildlife species, which can act as a source of infection for domestic small ruminants. PPR-infected countries are excluded from international trade of live small ruminants (OIE, 2020).

A PPR outbreak is an emergency due to its rapid spread and high animal mortality rate. Fatal diseases of small ruminants, such as PPR, affect the already vulnerable livelihoods and can decimate the savings of poor populations, especially in pastoral areas. People become desperate when they lose their assets. PPR outbreaks, and the desperation due to the loss, can trigger turmoil, migration, and volatile security situations (FAO, no date).

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Eradicating PPR will increase sustainability, alleviate poverty, improve the resilience of poor pastoralists and their communities, enable them to better cope with other shocks and threats, prevent forced migration and mitigate extremist trends (FAO, no date).

As an example, Mongolia reported its first-ever PPR outbreaks in sheep and goat populations in September 2016. In the absence of an adequate response by local veterinary services, the disease rapidly spread, devastating rural livelihoods, and disrupting exports and value chains. In December 2016, PPR spilled over to wild antelope species killing up to 60% of the Saiga antelope population, a critically endangered species according to the International Union for Conservation of Nature (IUCN) (FAO, no date).

PPR is not a zoonotic infection. There is no known risk of human infection with PPR virus (FAO, no date).

Metrics and numeric limits

Peste des petits ruminants (PPR) is on the list of notifiable diseases. Members are obliged to report cases and outbreaks to the Organisation, according to the Terrestrial Animal Health Code (WOAH, no date).

Key relevant UN convention / multilateral treaty

WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) (WTO, 1994). https://www.wto.org/english/res_e/booksp_e/agrmntseries4_sps_e.pdf

United Nations. 2023. UN Recommendations on the Transport of Dangerous Goods - UN Model Regulations. https://unece.org/transport/dangerous-goods/un-model-regulations-rev-23

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: PPR easily spreads in areas experiencing civil conflict, resulting in insecurity, displacement of people, loss of assets, and greater need to remain mobile. In such areas, vaccination to raise herd immunity is difficult, and movement (displacement) of susceptible animals spread the disease. The introduction of infected animals to a naive population is another driver (WOAH, 2020).

Impacts: death of infected animals, spread of infection, trade ban (WOAH, 2020; 2024b).

Peste des petits ruminants (PPR) is a contagious transboundary disease which has severe negative socio-economic impacts on the income of livestock farmers and, in particular, the livelihoods and food security of the most vulnerable rural communities, notably of women. WOAH and the FAO, in their joint strategy for control and eradication of PPR, have set the goal of eradicating the disease by 2030 (WOAH, no date).

Peste des petits ruminants (PPR) poses a major threat to food security and livelihoods in around 70 countries. Up to 90 percent of herds are infected, and mortality rates can reach 70 percent. Effective and affordable vaccines that provide lifelong immunity make eradication achievable through targeted vaccination and improved surveillance. The Global Eradication Programme for PPR aims to eliminate the disease by 2030 with an investment of USD 1.9 billion. It promises significant economic benefits and improved food security for millions dependent on small ruminants (FAO, 2025).

Multi-hazard Context: Not Applicable.

Monitoring: The section and the table below offer an overview of monitoring for peste des petits ruminants. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Ministry of Agriculture, Ministry of Livestock, FAO Reference Centres, WOAH Reference Centres,
How is the Hazard Observed/Monitored/Forecast?	Through its global early warning system, FAO has been supporting Members with risk monitoring, assessment and forecasting for animal health threats to enhance preparedness and response to animal health threats: • The Global Animal Disease Information System, EMPRES-i+, plays a crucial role in supporting countries with early warning and early detection of animal disease outbreaks. By providing a comprehensive platform for real-time disease tracking, EMPRES-i+, enables monitoring and analysis of animal health threats effectively, collaborating closely with countries and regions on disease information sharing. This supports the dissemination of risk assessments and alerts for evidence-based decision-making. • FAO develops and maintains decision support tools that provide risk maps of existing and predicted risks of animal disease emergence, as well as other threats to the agri-food chain. • Additionally, FAO collaborates closely with international organizations like WHO and WOAH to verify disease information through integrated mechanisms such as the Epidemic Intelligence from Open Sources (EIOS), the

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	Global Early Warning System (GLEWS+), and the World Animal Health Information System (WAHIS) for WOAH-listed diseases. These collaborations allow for the dissemination of early warning alerts and risk assessments to Members, to enable timely responses to potential outbreaks. FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

Risk Management: vaccination program, movement control, improve biosecurity (WOAH, 2020; 2024b). Eradicating PPR is a major advance towards achieving the Sustainable Development Goals (UNDESA, no date). A one-time vaccination can immunise ruminants for life against PPR.

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Coordinating agency or organisation

Food and Agriculture Organization of the United Nations (FAO) and World Organization for Animal Health (WOAH).

Preliminary – Corrections Pending

BI0311 / BIOLOGICAL / Infectious Diseases (Human and Animal)

zoonosis

Rift Valley Fever (Human and Animal)

Definition

Rift Valley fever (RVF) is an acute haemorrhagic viral disease, affecting small and large ruminants and camels. RVF virus is a member of the *Phlebovirus genus*. The disease causes high mortality, especially in newborns and mass abortions in pregnant animals. Humans become infected from contact with tissues/blood of infected animals, including abortive material and through mosquito bites. Disease in humans presents as influenza-like illness, haemorrhagic fever, encephalitis and occasionally death (adapted from FAO, 2003; WHO, 2018; OIE 2020).

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Annotations

Synonyms

Fièvre de la Vallée du Rift (fr), Fiebre del Valle del Rift (es)

Additional scientific description

Human
• Rift Valley fever (RVF) is a viral zoonosis that primarily affects animals but also has the capacity to infect humans. Infection can cause severe disease in both animals and humans (WHO, 2018). • Rift Valley fever outbreaks in domesticated animals are often accompanied by human disease. The majority of human infections result from contact with the blood, other body fluids or organs of infected animals. Human infections have also resulted from the bites of infected mosquitoes. To date, no human-to-human transmission of the RVF virus has been documented (WHO, 2018). • Rift Valley fever (RVF) is a viral zoonosis that primarily affects animals but also has the capacity to infect humans. Infection can cause severe disease in both animals and humans (WHO, 2018). • Rift Valley fever outbreaks in domesticated animals are often accompanied by human disease. The majority of human infections result from contact with the blood or organs of infected animals. Human infections have also resulted from the bites of infected mosquitoes. To date, no human-to-human transmission of the RVF virus has been documented (WHO, 2018). RVF is an economically important disease and affects different species of animals and humans. Immunisation and vector control are the main strategies to reduce the incidence of RVF. (WHO, 2018, no date). • RVF virus is a member of the *Phlebovirus* genus. The virus was first identified in 1931 during an investigation into an epidemic among sheep on a farm in the Rift Valley of Kenya (WHO, 2018). Since then, outbreaks have been reported in sub-Saharan Africa. In 1977 an explosive outbreak was reported in Egypt, the RVF virus was introduced to Egypt via infected livestock trade along the Nile irrigation system. In 1997–1998, a major outbreak occurred in Kenya, Somalia and the United Republic of Tanzania following an El Niño event and extensive flooding. After infected livestock trade from the horn of Africa, RVF spread in September 2000 to

Saudi Arabia and Yemen, marking the first reported occurrence of the disease outside the African continent and raising concerns that it could extend to other parts of Asia and Europe (WHO, 2018).

Animal

- RVF is caused by RVF virus (RVFV), an arbovirus, transmitted by mosquitoes. Outbreaks of RVF in animals can be prevented by a sustained programme of animal vaccination. There are three commercially available vaccines: the inactivated RVF vaccine, produced in South Africa and Egypt, the live attenuated vaccine, based on the Smithburn virus strain, produced in South Africa and Kenya, and the more recently registered RVF Clone 13, produced by Onderstepoort Biological Products (OBP) in South Africa and by MCI Santé Animale in Morocco (Dungu, & Bouloy, 2021). The live attenuated Smithburn RVF vaccine is safe for use in all breeds of cattle, sheep and goats, but it may cause foetal abnormalities or abortion in pregnant animals. Inactivated RVF vaccine is also used in outbreak situations, and in pregnant animals, as the attenuated Smithburn vaccine is not suitable for this group (WOAH, 2024a). Most countries maintain a list of approved veterinary vaccines for use. For specific regulations, consult the country's veterinary authorities.
- RVF virus is able to infect many species of animals causing severe disease in domesticated animals including cattle, sheep, camels and goats (WHO, 2024). The disease occurs in climatic conditions favouring the breeding of mosquito vectors and is characterised by abortion, neonatal mortality and liver damage. The disease is most severe in sheep, goats and cattle. Older non-pregnant animals, although susceptible to infection, are more resistant to clinical disease. Camels usually have an inapparent infection with RVF virus (RVFV), but sudden mortality, neonatal mortality and abortion occur, and abortion rates can be as high as in cattle (WOAH, 2024a).
- Aedes mosquitoes acquire the virus from feeding on infected animals, and may potentially vertically transmit the virus, so that new generations of infected mosquitoes may hatch from their eggs. This provides a potential mechanism for maintaining the virus in nature, as the eggs of these mosquitoes may survive for periods of up to several years in dry conditions. Once livestock is infected, a wide variety of mosquito species may act as vectors for transmission of RVFV and can spread the disease (WOAH, 2024a). Thus, RVF epidemic/epizootic has been associated with periods of flooding following heavy rainfall especially after a long drought. These floods create pools of water conducive for hatching/emergence of Aedes mosquitoes, which may be infected with the RVFV and can transmit the virus to ruminants or camels when they drink from or feed close to the water pools (FAO, 2003).
- RVF is one of the World Organisation for Animal Health (WOAH) listed diseases (WOAH, 2024b)

Metrics and numeric limits

Until 1975, RVF was regarded as an African, animal disease. Human cases were rare and with mild clinical manifestations. Severe outbreaks of haemorrhagic fever cases and fatalities in humans were reported in South Africa in 1975, Egypt in 1977 and Mauritania in 1987. One of the most noticeable outbreaks occurred in East Africa in December 1997, when unexplained human deaths were reported in the northeastern province of Kenya and southern Somalia. This epidemic was considered the most devastating in the region. In September 2000, RVF was detected for the first time outside the African continent, in Saudi Arabia and Yemen, leading to human deaths and major losses in livestock populations. In 2006-07 an outbreak was declared in Kenya. Tanzania and Somalia were affected later. Madagascar and South Africa were hit in 2007 and 2008 (ECDC, no date)

Key relevant UN convention / multilateral treaty

International Health Regulations (2005), 3rd ed. (WHO, 2016).

WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) (WTO, 1994).

United Nations. 2023. UN Recommendations on the Transport of Dangerous Goods - UN Model Regulations Model Regulations. https://unece.org/transport/dangerous-goods/un-model-regulations-rev-23. Accessed 1 January 2025.

Examples of hazard drivers, impacts, and risk management

Hazard drivers and impacts

Human

Hazard Drivers: Several different species of mosquito can act as vectors for transmission of the RVF virus. The dominant vector species varies between different regions and different species can play different roles in sustaining the transmission of the virus. During major outbreaks in primary foci, the disease can spread to secondary foci through livestock movement or passive mosquito dispersal and amplifies in naïve ruminants via local competent mosquitoes like Culex, Mansonia and Anopheles that act as mechanical vectors. Irrigation schemes, where populations of mosquitoes are abundant during long periods of the year, are highly favourable places for secondary disease transmission (WHO, 2018).

Impacts: The incubation period (the interval from infection to onset of symptoms) for RVF varies from 2 to 6 days. The most common form of the disease in humans is a self-limiting, flu-like illness. Complications in a minority of cases include ocular disease, neurological signs, kidney dysfunction and a life-threatening haemorrhagic syndrome with hepatic dysfunction. Although overall case fatality rates are thought to be low (≤2%), there may be a very large number of cases during some epidemics, resulting in hundreds of serious cases and significant numbers of deaths (Spickler, 2015; WHO, no date).

Animal

Hazard Drivers: RVF-infected mosquitoes; flash floods caused by unusual rainfall in an area where RVF occurred in the past; lack of

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biosecurity in handling aborted foetuses/slaughtered carcasses. **Impacts**: Abortion and/or death of infected animals and humans, spread of infection, trade ban.

Multi-hazard Context: Bites of infected mosquitoes; flash floods caused by unusual rainfall in an area where RVF occurred in the past; and lack of biosecurity in handling aborted foetuses/slaughtered carcasses are the main drivers in humans. RVF outbreaks in East Africa are closely associated with the heavy rainfall that occurs during the warm phase of the El Niño-Southern Oscillation (ENSO) phenomenon. RVF is considered an occupational disease of livestock handlers, dairy farmers, abattoir workers and veterinarians. The direct socio-economic impact of RVF is on livestock producers due to high levels of mortality and morbidity in animals (WHO, 2018, no date).

Monitoring: The table below offers an overview of monitoring for Rift Valley Fever. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Ministry of Agriculture, Ministry of Livestock, Ministry of Health, FAO Reference Centres, WOAH Reference Centres
How is the Hazard Observed/Monitored/Forecast?	Through its global early warning system, FAO has been supporting Members with risk monitoring, assessment and forecasting for animal health threats to enhance preparedness and response to animal health threats: • The Global Animal Disease Information System, EMPRES-i+, plays a crucial role in supporting countries with early warning and early detection of animal disease outbreaks. By providing a comprehensive platform for real-time disease tracking, EMPRES-i+, enables monitoring and analysis of animal health threats effectively, collaborating closely with countries and regions on disease information sharing. This supports the dissemination of risk assessments and alerts for evidence-based decision-making. • FAO develops and maintains decision support tools that provide risk maps of existing and predicted risks of animal disease emergence, as well as other threats to the agri-food chain. • Additionally, FAO collaborates closely with international organizations like WHO and WOAH to verify disease information through integrated mechanisms such as the Epidemic Intelligence from Open Sources (EIOS), the Global Early Warning System (GLEWS+), and the World Animal Health Information System (WAHIS) for WOAH-listed diseases. These collaborations allow for the dissemination of early warning alerts and risk assessments to Members, to enable timely responses to potential outbreaks. FAO empres-i+ https://empres-i.apps.fao.org/diseases Rift Valley fever (RVF) Early Warning Decision Support Tool (RVF DST) WOAH WAHIS https://wahis.woah.org/#/event-management

WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country risk profile. Empowered with the country's risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARSs should re-integrate back into the national system (WHO, no date a).

Risk Management: During an outbreak of RVF, close contact with animals, particularly with their body fluids, either directly or via aerosols, has been identified as the most significant risk factor for RVF virus infection. Raising awareness of the risk factors of RVF infection as well as the protective measures individuals can take to prevent mosquito bites is the only way to reduce human infection and deaths. For animal risk management, FAO recommends vaccination programmes, movement control, improved biosecurity and waterbody management. Restricting or banning the movement of livestock may be effective in slowing the expansion of the virus from infected to uninfected areas. (WHO, 2018).

As outbreaks of RVF in animals precede human cases, the establishment of an active animal health surveillance system to detect new cases is essential in providing early warning for veterinary and human public health authorities. Other ways in which to control the spread of RVF involve control of the vector and protection against their bites. As an example of a coordinated response, in the 2016 Niger outbreak, the World Health Organization (WHO) sent a multisectoral national rapid response team, including members from the Ministry of Health, veterinary services and Centre de Recherche Médicale et Sanitaire (CERMES). The unit was deployed

Preliminary – Corrections Pending

for field investigation on 31 August 2016. In Niger, the WHO Country Office provides technical and financial support for surveillance, outbreak investigation, technical guidelines regarding case definition, case management, shipment of samples, and risk communication. The Food and Agriculture Organization of the United Nations (FAO), the World Organisation for Animal Health (OIE), and the WHO are coordinating animal and human health and providing additional support to Niger for the outbreak response (WHO, 2018).

An inactivated vaccine has been developed for human use. However, this vaccine is not licensed and is not commercially available. It has been used experimentally to protect veterinary and laboratory personnel at high risk of exposure to RVF. Other candidate vaccines are under investigation (WHO, 2018).

Forecasting can predict climatic conditions that are frequently associated with an increased risk of outbreaks and may improve disease control. In Africa, Saudi Arabia and Yemen. RVF outbreaks are closely associated with periods of above-average rainfall. The response of vegetation to increased levels of rainfall can be easily measured and monitored by Remote Sensing Satellite Imagery. The association of RVF outbreaks with the heavy rainfall that occurs during the warm phase of the El Niño-Southern Oscillation (ENSO) phenomenon have been documented in East Africa. These findings have enabled the successful development of forecasting models and early warning systems for RVF using satellite images and weather/climate forecasting data. Early warning systems, such as these, could be used to trigger the detection of animal cases at an early stage of an outbreak, enabling authorities to implement measures to avert impending epidemics. Within the framework of the new International Health Regulations (2005), the forecasting and early detection of RVF outbreaks, together with a comprehensive assessment of the risk of diffusion to new areas, are essential to enabling the implementation of effective and timely control measures (WHO, 2018).

Rift Valley fever (RVF) Early Warning Decision Support Tool (RVF DST): The Food and Agriculture Organization of the United Nations (FAO) has developed a web-based Rift Valley fever (RVF) Early Warning Decision Support Tool (RVF DST), which integrates near real-time RVF risk maps with geospatial data, RVF historical and current disease events from EMPRES Global Animal Disease Information System (EMPRES-i) and expert knowledge on RVF eco-epidemiology.

The widening geographic range of disease is associated with climatic variations, with the likely impact of wider dispersal of the virus to new areas of endemicity and future epidemics. Climatic variables including rainfall, temperature, humidity and normalised difference vegetation index (NDVI), livestock production system, and land-use change are influencing this widening range (Situma et al., 2024).

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WTO, 1994. The WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement). World Trade Organization (WTO). https://www.wto.org/english/tratop_e/sps_e/spsagr_e.htm Accessed 24 May 2025.

Coordinating agency or organisation

Food and Agriculture Organization of the United Nations (FAO), World Health Organization (WHO), World Organisation for Animal Health (WOAH).

Preliminary – Corrections Pending

BI0312 / BIOLOGICAL / Infectious Diseases

Rinderpest (Animal)

Definition

Rinderpest was an acute, highly contagious viral disease of wild and domesticated ruminants and pigs, characterized by sudden onset of fever, oculonasal discharges, necrotic stomatitis, gastroenteritis and death. Rinderpest was eradicated in 2011 (FAO and OIE, 2011).

Reference

Joint FAO/OIE Committee on Global Rinderpest Eradication, 2011. Final report. FAO and OIE. May 2011
https://www.woah.org/fileadmin/Home/eng/Media_Center/docs/pdf/Final_Report_May2011_B.pdf
Accessed 28 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Peste bovine (fr), Peste bovina (es), Чума крс (ru).

Additional_scientific_description

Rinderpest is considered an eradicated disease. In case sick animals presenting rinderpest-like clinical signs (4Ds i.e. oculonasal discharge, diarrhoea, dehydration and deaths) are found and spreading fast, report it immediately to the official Veterinary Service office (FAO, 2016); WOAH Members are obliged to notify WOAH of important epidemiological events, such as suspected cases of rinderpest, through an immediate notification using the World Animal Health Information System (WAHIS); Non-WOAH Members should inform FAO (Rinderpest-Secretariat@fao.org) without delay.

Rinderpest was caused by paramyxovirus in the genus Morbillivirus. Rinderpest was capable of causing devastating losses (FAO, 1999). The disease was most commonly observed in domestic cattle and buffalos. Many species of wild and domestic cloven-hoofed animals (including sheep and goats) showed only mild clinical signs of the disease when infected, but for cattle and buffalo, mortality rates can reach 100% in highly susceptible herds. In cattle, the most susceptible species, classical signs of the disease included fever, erosive lesions in the mouth, discharge from the nose and eyes, profuse diarrhoea and dehydration, often leading to death within 10 to 15 days. In other species, rinderpest may show milder clinical signs (OIE, 2016). Asian domestic sway-backed pigs could also suffer from and succumb to rinderpest. Infection was also confirmed in many wild even-toed ungulates belonging to the order Artiodactyla: African buffalo, eland, kudu, warthog, bongo, bushbuck, bush pig, chevrotain, dik-dik, duiker, giant forest hog, giraffe, sitatunga, wildebeest in Africa; and banteng, blackbuck, gaur, nilgai and sambar in Asia (FAO, 1996). The global eradication of rinderpest, proclaimed in 2011, was a major milestone that parallels the extermination of smallpox worldwide in 1980. Both diseases, although caused by distinctly different viruses, inflicted untold misery and death for centuries and both diseases were finally overcome through the use of vaccines (FAO & OIE, 2022).

Metrics_and_numeric_limits

Rinderpest, also known as cattle plague, is a contagious viral disease affecting cloven-hoofed animals (mainly cattle and buffalo). In 2011, rinderpest became the second disease to be declared officially eradicated, following the eradication of the human disease smallpox in 1980 (WOAH, no date).

Key_relevant_UN_convention_/_multilateral_treaty

WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) (WTO, 1994).
https://www.wto.org/english/res_e/booksp_e/agrmntseries4_sps_e.pdf

UN Recommendations on the Transport of Dangerous Goods - UN Model Regulations Model Regulations (UNECE, 2023). https://unece.org/transport/dangerous-goods/un-model-regulations-rev-23

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Although rinderpest no longer occurs in livestock, the rinderpest virus-containing material is being stored in a few laboratories across the world where it poses a risk through inadvertent or malicious release (Myers et al., 2018). Virus escape from a laboratory and introduction to susceptible animals. Outcomes: death of infected animals, spread of infection, production loss, famine, trade ban, loss of global freedom from rinderpest.

Before its eradication, rinderpest easily spread in areas experiencing civil conflict, resulting in insecurity, displacement of people, loss of assets, and greater need to remain mobile. In such areas, vaccination to raise herd immunity was difficult, and movement (displacement) of animals spread the disease. After the eradication, bioterrorism is a concern.

Impacts: High mortality in cattle, trade ban, livelihoods and food security implications.

Multi-hazard Context: Not Applicable

Monitoring: The section and the table below offer an overview of monitoring for rinderpest. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	FAO Reference Centres, WOAH Reference Centres,
How is the Hazard Observed/Monitored/Forecast?	FAO empres-i+ https://empres-i.apps.fao.org/diseases WOAH WAHIS https://wahis.woah.org/#/event-management

Risk Management: Rinderpest remains a notifiable disease to the OIE, and adequate surveillance systems must be maintained to ensure early detection of clinical cases, should there be any accidental or intentional escape of the virus from high-containment storage facilities (OIE, 2016). Through the Global Rinderpest Action Plan (GRAP), FAO aims to ensure continued global freedom from rinderpest by outlining the actions necessary to prepare for, respond to and recover from an outbreak. The GRAP also entails optimizing capacity to make diagnostic tools and vaccines available if needed, a coordinated emergency plan that can be immediately activated upon the first confirmed case, assuring both a rapid return to global freedom from the disease and necessary support for affected livelihoods (FAO, no date).

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https://www.woah.org/fileadmin/Home/eng/Media_Center/docs/pdf/Disease_cards/RINDERPEST-EN.pdf Accessed 1 January 2025.

WOAH, 2024a. Manual of Diagnostic Tests and Vaccines for Terrestrial Animals, 13th edition. World Organisation for Animal Health (WOAH). https://www.woah.org/fileadmin/Home/eng/Health_standards/tahm/3.01.21_RINDERPEST.pdf Accessed 1 January 2025.

WOAH, 2024b. Terrestrial Animal Health Code. 32nd edition. World Organisation for Animal Health (WOAH). https://www.woah.org/en/what-we-do/standards/codes-and-manuals/terrestrial-code-online-access/?id=169&L=1&htmfile=chapitre_rinderpest.htm Accessed 1 January 2025.

Coordinating agency or organisation

Food and Agriculture Organization of the United Nations (FAO) and World Organisation for Animal Health (WOAH).

Preliminary – Corrections Pending

BI0313 / BIOLOGICAL / Infectious Diseases (Aquaculture)

Oyster Disease Aquaculture

Definition

There are a number of causal agents recognised for oyster diseases. Examples of major oyster diseases and their causal protozoan agents are: bonamiosis (*Bonamia exitiosa*, *B. ostreae*); marteiliosis (*Marteilia refringens*); perkinsosis (*Perkinsus marinus*, *P. olseni*). These oyster diseases are notifiable OIE-listed diseases and occur worldwide (WOAH, 2024).

Reference

WOAH, 2024. Manual of Diagnostic Tests for Aquatic Animals. World Organisation for Animal Health (WOAH). www.woah.org/en/what-we-do/standards/codes-and-manuals/aquatic-manual-online-access/ Accessed 12 March 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Not identified.

Additional scientific description

Aquatic food makes an important contribution to human health and development as an essential source of high-quality proteins, vitamins and micronutrients. Global aquaculture production is now a USD 157 billion industry, with USD 20.5 billion of this total representing the production of molluscs for food in the marine environment. The largest share of this represents the culture of bivalves such as oysters, clams and scallops. Mollusc culture is a well-developed industry in many countries, notably in the northern hemisphere, such as the USA, Canada, Japan, Korea, France, Spain and the Netherlands (Carnegie et al., 2016).

Oysters are subject to a number of diseases, which can impact the local population and reduce harvests in a commercial setup.

The agents causing oyster diseases do not pose any direct human health implications. However, oysters could potentially pose a health concern for humans in cases where they contain high levels of Vibrio spp. (*V. parahaemolyticus*, *V. vulnificus*, and choleragenic, *V. cholera*) and are consumed raw, or where the oysters are produced in an area containing biotoxin or heavy metal contamination (e.g., lead) (WHO, 2005). Bivalve molluscs are filter feeders; therefore, they are susceptible to picking up and accumulating toxins, and chemical or bacteriological contaminants from their environment. By filtering a great quantity of water, they may bioaccumulate a high number of microorganisms in their tissues that can be considered infectious for humans and higher vertebrates (Zannella et al., 2017). The causative pathogens live in aquatic environments in both tropical and temperate zones. High temperatures and salinities favour the proliferation of some of the pathogens.

Epizootic diseases have been shown to cause catastrophic mortality among marine bivalves, which can severely affect fisheries and aquaculture activities worldwide. Some of these diseases have become a serious constraint on the development and sustainability of shellfish farming and fishing. Currently, the main cause of epizootic outbreaks is thought to be the transfer of infectious agents through the transport of live shellfish.

Severe outbreaks have resulted in significant economic destruction, with some outbreaks essentially causing the collapse of entire industries. For instance, epizootics of protistan parasites *Haplosporidium nelsoni* in the 1950s to 1960s and *Perkinsus marinus* in the 1980s to 1990s devastated the planting industry for oyster *Crassostrea virginica* in the US mid-Atlantic (Carnegie et al., 2016).

Illness in humans is linked to the consumption of raw oysters.

Metrics and numeric limits

None identified.

Key relevant UN convention/multilateral treaty

Codex Alimentarius (FAO, no date).

WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) (WTO, 1994)

WTO and the World Organization for Animal Health (WOAH) (WTO, 2007).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: As a consequence of globalisation, urbanisation and global change, the number of emerging diseases of molluscs is increasing.

Impacts: These diseases have a significant impact on aquatic animals resulting from (i) a change of known pathogenic agent or its spread to a new geographical area or species, or (ii) a newly recognised or suspected pathogenic agent. Different scenarios can lead to the emergence of diseases, but the cause is often the introduction of infected animals.

Multi-hazard Context: Not Applicable.

Monitoring: The section and the table below offer an overview of monitoring for oyster diseases in aquaculture. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	World Organisation for Animal Health (WOAH); Food and Agriculture Organization of the United Nations (FAO); Ministries of Fisheries
How is the Hazard Observed/Monitored/Forecast?	Mortality in open systems should be monitored for patterns of losses, and samples should be collected for further analysis. Samples may be examined for gross signs, including observation under a dissecting microscope for abnormalities and deformities, fouling organisms, and fixed for further processing.

Risk Management: The World Organisation for Animal Health (WOAH) Aquatic Animal Health Code has set out standards and recommendations to improve the safety of international trade in aquatic animals, including marine bivalve molluscs (WOAH, 2024). The aim is to prevent the pathogen's introduction into an importing country, so as to avoid the onset of disease outbreak rather than to eradicate the pathogen, which would be more difficult and expensive owing to the high-density production systems used in commercial hatcheries and nurseries and the continuous stock movements around the world (Zannella et al., 2017).

The OIE member countries are required to report the detection of listed and emerging diseases (Carnegie et al., 2016).

There is currently no available vaccine, treatment or chemical control agent for the WOAH-listed diseases of oysters, therefore the surveillance and control plan of these diseases based on their prevention have a key role. For this reason, it is important to implement high levels of on-farm and live-holding facility biosecurity and to restrict stock movements (Zannella et al., 2017).

Maintaining the biosecurity of international aquaculture industries requires control of pathogens of concern. This can include rapid detection in animals proposed for sale or transfer to prevent pathogen introduction to new areas and maintain

disease-free facilities and regions, and focused management of pathogens where they do occur, including the use of pathogen-resistant broodstocks to reduce the magnitude of seasonal epizootics (Carnegie et al., 2016).

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Preliminary – Corrections Pending

Organization (WTO). https://www.wto.org/english/tratop_e/sps_e/spsagr_e.htm Accessed 12 March 2025.

WTO, 2007. The WTO and the World Organization for Animal Health (OIE) G/SPS/GEN/775. World Trade Organization (WTO). www.wto.org/english/thewto_e/coher_e/wto_oie_e.htm Accessed 12 March 2025.

Zannella, C., Mosca, F., Mariani, F., Franci, G., Folliero, V., Galdiero, M., Tiscar, P.G., and Galdiero, M., 2017. Microbial diseases of bivalve mollusks: infections, immunology and antimicrobial defense. Marine Drugs, 15:182. www.ncbi.nlm.nih.gov/pmc/articles/PMC5484132 Accessed 12 March 2025.

Coordinating agency or organisation

Food and Agriculture Organization of the United Nations (FAO), World Organisation for Animal Health (WOAH)

Preliminary – Corrections Pending

BI0314 / BIOLOGICAL / Infectious Disease (Aquaculture)

Shrimp Disease (bacterial) - Acute Hepatic Pancreatic Necrosis

Definition

Shrimp acute hepatopancreatic necrosis disease (AHPND) is caused by virulent strains of *Vibrio parahaemolyticus* and related Vibrio species. AHPND-associated mortalities occur early in the production cycle, usually within 30 to 35 days of stocking, and because of this AHPND was initially referred to as early mortality syndrome (WOAH, 2023)

Reference

WOAH, 2023. Manual of Diagnostic Tests for Aquatic Animals: Acute Hepatopancreatic Necrosis Disease. Chapter 2.2.1. World Organisation for Animal Health (WOAH) www.woah.org/fileadmin/Home/eng/Health_standards/aahm/current/2.2.01_AHPND.pdf Accessed 12 March 2025

Preliminary – Corrections Pending

Annotations

Synonyms

Early mortality syndrome (EMS), Photorhabdus insect-related (Pir), Hepatopancreas (HP).

Additional scientific description

Acute hepatopancreatic necrosis disease (AHPND) is a bacterial disease that has caused mass mortalities in farmed populations of white leg shrimp and giant tiger prawn. The causative agent is virulent strains of *Vibrio parahemolyticus* and four other Vibrio species (*V. harvey, V. campbellii, V. owendii, V. punensis*). AHPND was listed by the World Organisation for Animal Health (OIE) as a notifiable disease in 2016 (OIE, 2019a).

The disease was initially reported in Asia in 2010. It has since been reported in the Americas (2013) and Africa (2017). See WOAH WAHIS for recent information on distribution at the country level (WOAH, 2023).

The causative agents, discovered in 2013, are isolates of V. parahaemolyticus and related Vibrio species that carry a 69-73 kbp plasmid (pVA1) containing pirABvp genes that produce proteins (12.7 kDa and 50.1 kDa) that act together to cause AHPND. The pirABvp toxin genes in these Vibrio species are similar to the pirAB toxin genes of *Photorhabdus spp.*, which are gram-negative, luminescent, rod-shaped bacteria in the Family Enterobacteriaceae (FAO, 2018). The PirAB has an insecticidal property; its toxicity results in severe swelling and shedding of the midgut epithelium in larvae of the moth *Plutella xylostella*.

Clinical signs and mortality of AHPND can start as early as 10 days post-stocking. Major clinical signs involve shrimp hepato-pancreas: significant atrophy, loss of colour, and the presence of black spots or streaks due to melanised tubules. Additional clinical signs include soft shells and an empty stomach or near-empty midgut (OIE, 2019a).

Metrics and numeric limits

Not available.

Key relevant UN convention / multilateral treaty

Not identified.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Acute hepatopancreatic necrosis disease is caused by unique strains of *V. parahaemolyticus* and four other Vibrio species. Vibrio bacteria are ubiquitous in marine and brackish-water environments, and their populations are affected in these

ecosystems by temperature, salinity, and turbidity. These AHPND-related bacteria can be present in both the cultured shrimp as well as in the water, sediments, and associated organisms in the farm ponds and in the surrounding aquatic environment (OIE, 2019a).

Impacts: No Information Available

Multi-hazard Context: Not Applicable.

Monitoring: The section and the table below offer an overview of monitoring for shrimp disease – acute hepatic pancreatic disease. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	World Organisation for Animal Health (WOAH); Food and Agriculture Organization of the United Nations (FAO); Ministries of Fisheries
How is the Hazard Observed/Monitored/Forecast?	Monitored and observed clinically through signs, including e.g. a pale-to-white, atrophied Hepatopancreas (HP), empty stomach and midgut, black spots or streaks visible within the HP (due to melanized tubules) and soft shells at the chronic phase of the disease.

Risk Management: Several therapeutic methods have been tried, with mixed results, to combat AHPND in populations of infected shrimp on farms, but there is a lack of scientific data to corroborate claims of their effectiveness. These include antibiotics, bacteriophage therapy, probiotics, etc. (FAO, 2020).

Since the emergence of AHPND, shrimp producers in Southeast Asia and Latin America have changed farm designs and operations to facilitate the management of this disease; such changes include the use of smaller, lined ponds; central drains; prefiltered clean water; tilapia for removal of sediments; increased aeration; frequent feeding regimes to reduce uneaten feed; and probiotics applied to the ponds. Biosecurity measures have been implemented such as the use of pathogen-free postlarvae and access control to the rearing site to prevent the introduction of pathogens. These management strategies seem to have been effective, as global shrimp production has shown a gradual recovery since 2016 (FAO, 2020).

Good aquaculture and biosecurity practices include farm management (screening prior to stocking; pond water and bottom preparation); proper destruction and disposal of diseased shrimp; disinfection of affected premises; vector control; containment through movement control and zoning; and avoiding sources of stress (high stocking density, poor water quality or other less optimal environmental conditions such as suboptimal temperature or salinity) (FAO, 2020).

The World Organisation for Animal Health (WOAH) provides recommendations on AHPND that include advice on importation, transit and maintenance of free status from AHPND (WOAH, 2024).

A report jointly published by the Food and Agriculture Organization of the United Nations (FAO) and the Asian Fisheries Society in 2018, aimed at updating knowledge and experience in dealing with AHPND and related topics from the perspective of government, academe and producer sectors (FAO, 2018).

References

FAO, 2018. FAO Technical Assistance Efforts to Deal with Acute Hepatopancreatic Necrosis Disease (AHPND) of Cultured Shrimp. Food and Agriculture Organization of the United Nations (FAO). www.asianfisheriessociety.org/publication/download-file.php?id=1217&file=Y0dSbUx6QXhOVFF5TWpNd01ERTFORGMzTXpJM05UZ3VjR1Jt Accessed 12 March 2025.

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Preliminary – Corrections Pending

Coordinating agency or organisation

Food and Agriculture Organization of the United Nations (FAO), World Organisation for Animal Health (WOAH).

Preliminary – Corrections Pending

BI0401 / BIOLOGICAL / Insect Infestation

Insect Pest Infestations

Definition

An insect pest infestation is a recently detected insect pest population, including an incursion, or a sudden significant increase of an established insect in an area leading to damage to plants in production fields, forests or natural habitats and causing substantial damage to productivity, biodiversity or natural resources (adapted from IPPC Secretariat, 2024).

Reference

IPPC Secretariat, 2024. Glossary of phytosanitary terms. International Standard for Phytosanitary Measures No. 5. Rome. FAO on behalf of the Secretariat of the International Plant Protection Convention. https://assets.ippc.int/static/media/files/publication/en/2024/07/ISPM_05_2024_En_Glossary_PostCPM-18_InkAmdts_2024-07-29.pdf Accessed 20 March 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Insect invasion, outbreak

Additional scientific description

Insects are responsible for significant losses to the world's crop production. Not all insects are pests, but many are harmful to crops, forest trees, livestock and humans. One major reason for the occurrence of these pests is the expansion of monocultures in large areas at the expense of natural habitats and diverse plants, with crops and trees selected for their large size, high yield and economic value. This provides a highly conducive environment for herbivorous insects. In addition to agroecosystem-based integrated management practices during production, good post-harvest management and storage conditions are important in reducing losses caused by insect infestation in agriculture (FAO, no date).

A detailed glossary of phytosanitary terms was developed for the International Standards for Phytosanitary Measures. It was produced by the Secretariat of the International Plant Protection Convention for the Food and Agriculture Organization of the United Nations (FAO). Examples of relevant terms for insect pest infestation are given below (FAO, 2024):

- Biological control agent: A natural enemy, antagonist or competitor, or another organism, used for pest control.
- Incidence (of a pest): Proportion or number of units in which a pest is present in a sample, consignment, field or other defined population.
- Incursion: An isolated population of a pest recently detected in an area, not known to be established, but expected to survive for the immediate future.
- Infestation (of a commodity): Presence in a commodity of a living pest of the plant or plant product concerned. Infestation includes infection.
- Introduction (of a pest): The entry of a pest resulting in its establishment in the environment.
- Official control: The active enforcement of mandatory phytosanitary regulations and the application of mandatory phytosanitary procedures with the objective of eradication or containment of quarantine pests or the management of regulated non-quarantine pests.
- Outbreak: A recently detected pest population, including an incursion, or a sudden significant increase of an established pest population in an area.
- Pest: Any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products. Note: In the

International Plant Protection Convention (IPPC), 'plant pest' is sometimes used for the term 'pest' (FAO, 2024):

Insect pest infestations can devastate not only the crops but also the forests. For example, *Agrilus planipennis Fairmaire,* Family Buprestidae, order Coleoptera was established in 1888 by Fairmaire. *Agrilus* is regarded to be the most speciose genera in the animal kingdom with more than 3000 recorded species (Kelnarova et al., 2019). The emerald Ash borer is an East Asian (China, Japan, Korea and Mongolia) wood-boring beetle. It was first observed on *Fraxinus* trees in the USA and quickly spread to some provinces of Canada. The pest was reported in the EPPO region - in the European part of Russia - in 2003 and later detections were made in eastern Ukraine in 2019 (Orlova-Bienkowskaja et al., 2020). Since its arrival in North America, *A. planipennis* has killed tens of millions of its ash trees, *Fraxinus* spp. and *Chionanthus virginicus* (Fringetree). This invasive insect pest has been introduced through plant material of host into EU member states and poses a serious threat to the ecological and economic values of forest resources. Larvae feed on the phloem of infested ash causing extensive dieback and tree death. The beetle requires one year to complete one generation or two years in colder climates. Adults are found in spring and summer (EFSA, 2023).

Metrics and numeric limits

Invasive insect species impact can be measured using various metrics, including landscape metrics, functional diversity, and relative impact potential. Landscape metrics like habitat patch aggregation and shape complexity can be used to assess the effects of habitat fragmentation on invasive insect spread. Functional diversity metrics, such as functional richness and evenness, can help understand the impact of invasive insects on native plant communities. For example, the Relative Impact Potential (RIP) metric combines the per capita effects of invaders with their abundance to predict their likelihood and degree of ecological impact (Dickey et al., 2020).

Key relevant UN convention / multilateral treaty

The International Plant Protection Convention (1997) is an intergovernmental treaty signed by over 180 countries, aiming to protect the world's plant resources from the spread and introduction of pests and promote safe trade (FAO, 2011). The Convention introduced international standards for phytosanitary measures as its main tool to achieve its goals, making it the sole global standard-setting body for plant health (FAO, 2005). The IPPC is one of the 'Three Sisters' recognized by the World Trade Organization's (WTO) Sanitary and Phytosanitary Measures (SPS) Agreement, along with the Codex Alimentarius Commission for food safety standards and the World Organization for Animal Health (OIE) for animal health standards.

The Convention on Biological Diversity (1992) has three main objectives: the conservation of biological diversity, the sustainable use of the components of biological diversity, and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources (United Nations, 1992). At the time of writing, there were 196 parties to the Convention on Biological Diversity (Convention on Biological Diversity, 2021).

Codex Alimentarius (Codex Alimentarius, no date).

WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) (1994) (WTO, no date).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: The agriculture and forestry sectors face many risks, such as climate and market volatility, pests and diseases, extreme weather events, and an ever-increasing number of protracted crises and conflicts. Issues around outbreaks of animal and plant pests and diseases are of major concern due to their role in biological disasters and in many food chain emergencies.

Favourable climatic conditions, disruption of ecosystems and negligence of crop/forest hygiene contribute to growth in insect populations which can cause substantial damage regularly. In many cases, the long-distance spread of insects results from the transportation of infested goods.

Higher temperatures, severe and extreme weather events and drought stress can all result in reduced vigour of trees, making them more vulnerable to outbreaks of native and introduced pests and diseases. For example, the dieback of millions of hectares of pine forests caused by outbreaks of native bark beetles in Central America, Europe and North America is associated with climate change, impacts of extreme weather events and, in some cases, inadequate forest management practices (FAO, 2020a).

Impacts: The food chain is under continuous threat with an alarming increase in the number of outbreaks of transboundary animal and plant pests and diseases. Crop pests, forest pests and animal diseases are among the costliest disasters in Africa – more so than in Latin America and Asia – accounting for over USD 6 billion in agricultural loss between 2005 and 2015, with insect pests ravaging up to 85 million hectares of forests, mainly in temperate North America (FAO, 2018).

There are over a million species of insects. These include some key species causing direct damage to crops, and natural vegetation such as locusts, grasshoppers, armyworms and fruit flies as well as those that also function as vectors for the transmission of plant disease agents such as white flies, aphids, spittlebugs and mealybugs (FAO, 2021).

The most recent global-scale insect pest infestation is caused by fall armyworm (FAW) spreading to almost the whole of Africa and south and southeast Asia following its jump from Latin America to Africa in 2016. It is currently causing damage to millions of hectares, particularly on maize but also other crops, creating significant food security risks. The Food and Agriculture Organization of the United Nations (FAO) has launched a Global Action for FAW Control to facilitate international collaboration to combat the

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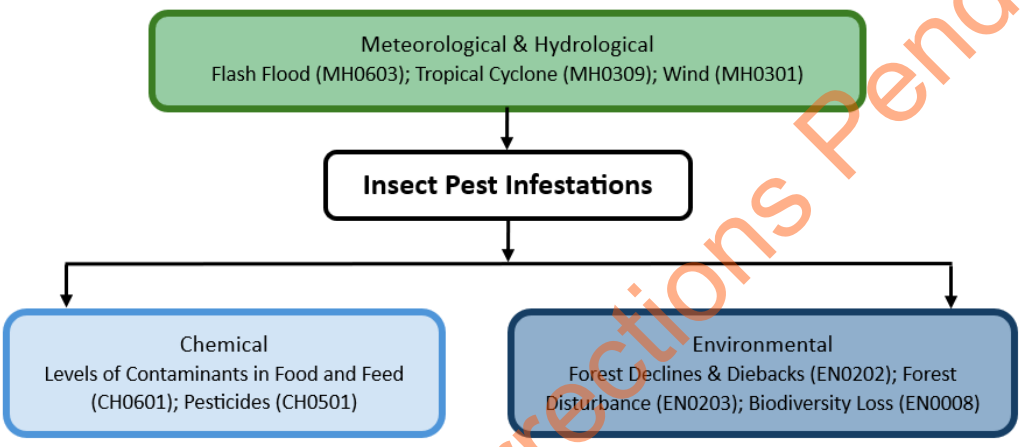
insect (FAO, 2020b).

Insect pest infestations may cause food security challenges especially if the staple food crops are affected. They can also result in market or price instability. In certain cases, such infestations can cause severe food insecurity as in the case of desert locust upsurges in the Horn of Africa and Yemen in 2020-21 (FAO, 2022). Similarly, the rapid expansion of fall armyworms in Africa and Asia has put many countries in difficult positions to protect crops, particularly of smallholder farmers.

In addition to the impact on food security, insect pest infestations can also devastate natural landscapes. Other implications on local populations can include local conflicts or migration due to shortages in severe cases, happen in severe locust upsurges. Furthermore, in certain cases, insecticide sprays can have implications concerning the health of local habitants.

Multi-hazard Context: The figure below summarises common interactions between insect pest infestations and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring for insect pest infestations. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	At global level, the pest reporting system of IPPC can be considered the most official resource for reports of the occurrence of quarantine plant pests including diseases (IPPC, 2025). Although in most cases such reports are deposited well after the establishment of a pest, these can be considered as early warning resources for other concerned countries. In this respect, the most efficiently functioning monitoring and early warning system is the desert locust monitoring system operated by FAO. The system is run by the Desert Locust Information Service (DLIS) and supported by three commissions (Western Region, Central Region and Southwest Asia) as well as the desert locust control committee (DLCC) (FAO, 2025a).
How is the Hazard Observed/Monitored/Forecast ?	The system utilizes a network of concerned countries that run surveys and share data over satellite tools with the Desert Locust Information Service (DLIS) operating since 1978 (FAO, 2025b), and housed at the headquarters of FAO, where the data is analysed together with geospatial and meteorological data. Analysis helps monitoring of the overall situation and production of forecasts and early warning for potential outbreaks to be shared with the concerned countries publicly. Other insects are monitored through official reports of countries, network communications, direct communications and public news. The pest reporting system and the IPPC facilitate the monitoring of officially reported pests (IPPC, 2025a, b)

Several monitoring systems focus on plant pests and diseases particularly at the regional level, such as those in Europe (Peter et al., 2011) and North America (Meissner et al., 2015).

Risk Management: Following principles of sustainable plant production, sustainable forest management and integrated pest management practices are the best approach for control, focusing on diversified production systems, regular surveillance, preparedness before potential outbreaks, and a rapid response to prevent escalation to unmanageable scales (Guzewich et al., 1997).

Improving national capacities in preparedness, contingency planning, surveillance and rapid response is crucial for preventing infestations and mitigating their impact. Likewise, international cooperation, data sharing and knowledge exchange are essential for addressing transboundary infestations and upsurges. Good examples of international collaboration include risk-informed response to the expansion of fall armyworm across Africa and Asia as well the desert locusts upsurge in 2020-21. FAO has developed and

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implemented several global initiatives to address these challenges (FAO, 2020c). In the case of desert locusts, collective efforts by FAO, governments and partners averted 4.5 million tonnes of crop losses, saved 900 million litres of milk production and secured food for nearly 42 million people (FAO, 2022).

Post-disaster needs assessment (PDNA) is designed to evaluate immediate needs for recovery and restoration for better disaster response. The focus of this mission, however, is on estimating socioeconomic impact; and currently does not take into account longer-term damage and loss caused to natural environments and forests. In addition, damage caused by small-scale fires, small windthrow events, and localised pest infestations remains largely unreported, despite meeting the universally established definition of a disaster (FAO, 2018).

Regarding insect pest infestations in forests, much of what is currently known about the damage and its assessment is in the form of research reports on the application of remote sensing and does not constitute a solid basis for a rigorous sector-specific assessment (FAO, 2018). In the case of Emerald Ash Borer infestations, the spread of the insect imposes important biodiversity losses and substantial costs on forestry and urban management. This affects forest-dependent communities whose incomes are directly tied to the health and productivity of forest ecosystems. As ash trees decline, industries such as logging, woodworking, and nurseries suffer, leading to reduced income for those who rely on these activities. Additionally, non-timber forest products, like nuts and medicinal plants which thrive under the canopy of ash trees, are also affected, further impacting vital ecosystem services for rural communities.

International knowledge sharing and collaboration is critical for establishing early warning communications. At global level, the pest reporting system of IPPC can be considered the most official resource for reports of the occurrence of quarantine plant pests including diseases (IPPC, 2025). Although such reports are deposited well after the establishment of a pest, they still can serve as early warning resources for other affected countries. One of the most efficient functioning monitoring and early warning systems is the desert locust monitoring system operated by FAO. The system is supported by three commissions (Western Region, Central Region and Southwest Asia) as well as the desert locust control committee (DLCC) (FAO, 2025a). The system utilizes a network of concerned countries that run surveys and share data over satellite tools with the Desert Locust Information System (DLIS) operating since 1978 (FAO, 2025b), and is housed at the headquarters of FAO. Data collected is analysed together with geospatial and meteorological data, helping monitor the overall situation and produce forecasts and early warnings for potential outbreaks which are shared publicly with the concerned countries. Similar tools are currently being developed for locust monitoring in Central Asia and Caucasus (FAO, 2025c), for the monitoring of fall armyworm at the global level (FAO, 2025d). At regional scale, a monitoring tool was developed for red palm weevil monitoring in the Near East.

Regarding the emerald ash borer, infested trees show distinctive symptoms and signs, but due to their late appearance, surveillance based on symptoms is not suited for detection at low insect densities. The use of traps baited with attractants targeting adult beetles is an effective method to detect the pest at the early stages of infestation and is the recommended approach for implementing surveillance within the EU. (EFSA, 2023).

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Coordinating agency or organisation

Food and Agriculture Organization (FAO), International Plant Protection Convention (IPPC).

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BI0402 / BIOLOGICAL / Insect Infestation

Locust upsurge

Definition

Widespread and heavy infestations of crops and natural vegetation by locusts causing significant threats to food security, livelihoods and natural habitats in multiple regions (adapted from FAO, 2009a).

Reference

FAO, 2009a. Glossary on Desert Locust. Food and Agriculture Organization of the United Nations (FAO). www.fao.org/3/a-as983b.pdf Accessed 27 May 2025.

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Annotations

Synonyms

Locust outbreaks, Locust upsurges, Locust plagues

Additional scientific description

Locusts are a member of a large group of insects commonly called grasshoppers which have big hind legs for jumping. Locusts belong to the family called Acrididae (FAO, 2025a). All grasshoppers belong to the superfamily Acridoidea, and the most significant species are all in the family Acrididae. Locusts differ from other grasshoppers in that they have the ability to change their behaviour, physiology, colour and shape (morphology) in response to changes in their population density. The life cycle of all species of locusts and grasshoppers comprises three stages: egg, hopper, and adult (FAO, 2009a).

A plague of locusts is defined as a period of one or more years of widespread and heavy locust infestations, the majority of which occur as bands or swarms. A plague can occur when favourable breeding conditions are present, and control operations fail to stop a series of local outbreaks from developing into an upsurge that cannot be contained. A major plague exists when two or more regions are affected simultaneously (FAO, 2009a).

The Desert Locust (*Schistocerca* gregaria) is able to fly long distances and migrate very fast. It is a transboundary pest, whose control requires international collaboration. This is also the case for about a dozen other locust species, which can produce outbreaks on every continent except Antarctica (FAO, 2015). During outbreaks, upsurges and plagues, locusts attack and destroy pasturelands and a wide range of cultivated crops, including cereals, cucurbits, legumes, sunflowers, tobacco, vegetables, vines, fruit trees, cotton and other plants.

The Desert Locust is considered the most dangerous migratory pest in the world to threaten crop production and food security. It might be the oldest registered pest for its danger and ability to live and breed under wide-ranging ecological and climatic regimes, in vast areas covering 29 million km2 and extending from the Atlantic Ocean in the west to India and Pakistan in the east (FAO, 2009a). During plagues, swarms can invade more than 60 of the world's poorest countries and potentially damage the livelihoods of one tenth of the world's population, mostly in Africa, the Middle East and Asia (FAO, 2015).

The worst Desert Locust outbreak of the last 25 years took place in the Near East, the Greater Horn of Africa and Southwest Asia in 2020-2021 (FAO, 2022a). Tens of thousands of hectares of cropland and pasture were damaged in Ethiopia, Kenya and Somalia where food security is already fragile. As a consequence, 36.6 million people in locust-affected countries faced crisis-level food insecurity (FAO, 2022b).

Species other than Desert Locusts can also cause significant damage under favourable conditions in different parts of the world. These include the Italian Locust and the Moroccan Locust in the Caucasus and Central Asia, the Red Locust in Eastern Africa, the Brown Locust in Southern Africa, the Migratory Locusts in Africa and Asia, the Tree Locust in Africa, and the Australian Plague Locust in Australia (FAO, 2020c; 2020d).

Locusts are also serious threats to agriculture in The Caucasus and Central Asia. The borders of countries in the region are often located across traditional locust habitats and breeding areas, and locusts frequently cross countries' political borders.

As a result, international collaboration is critical for their control in the region. Three main locust pests, the Asian Migratory Locust (*Locusta migratoria migratoria*), the Italian Locust (*Calliptamus italicus*) and the Moroccan Locust (*Dociostaurus maroccanus*) jeopardise food security and livelihoods in both regions as well as in adjacent areas of northern Afghanistan and southern Russian Federation, putting over 25 million hectares of cultivated areas potentially at risk.

Metrics and numeric limits

Not available.

Key relevant UN convention / multilateral treaty

The Food and Agriculture Organization of the United Nations (FAO) Desert Locust Control Committee (FAO, 2020b).

The FAO regional Desert Locust Commissions (FAO, 2009b).

Examples of hazard drivers, impacts, and risk management

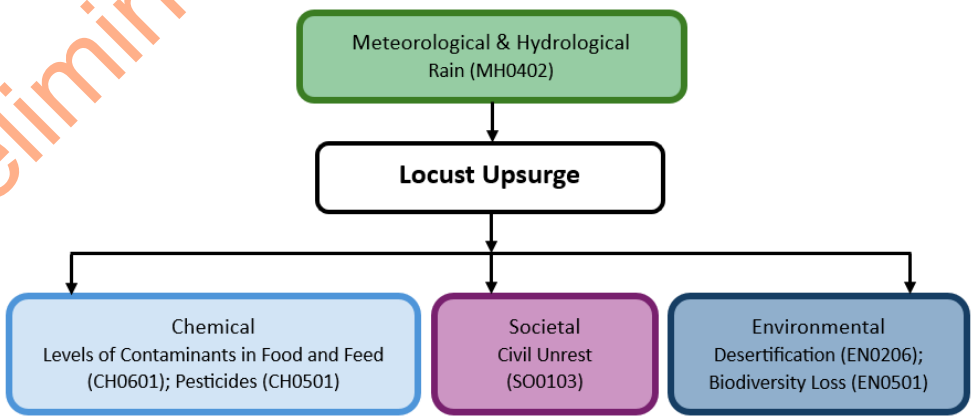
Hazard Drivers: Locusts are known as the most destructive invasive plant pests. Locusts have a high capacity to multiply, form groups, migrate over relatively large distances (they can fly up to 100 km per day) and settle and breed in various habitats. These capacities enhance their prevalence at the regional level. Highly mobile and capable of stripping an area's vegetation, locust swarms can cause large-scale agricultural and environmental damage. Even a relatively small locust swarm can eat the same amount of food in one day as about 35,000 people. This can be especially devastating in countries facing food security crises, where every gram of food produced counts towards alleviating hunger (FAO, 2020c).

Impacts: Locusts have the ability to change their behaviour and appearance under particular environmental conditions (unusually heavy rains) and to transform themselves from harmless individuals to a collective mass of insects that forms swarms. During quiet periods (known as recessions), solitarious locusts are found in low numbers scattered throughout the deserts of North Africa, the Middle East and Southwest Asia (Desert Locust). This arid area is around 16 million km² in size and includes about 30 countries. It is called the recession area. In severe cases, the swarms can invade an area of land equivalent to about 20% of Earth's surface (FAO, 2015).

Locust upsurges may cause food security challenges especially if the staple food crops are affected. They can also result in market or price instability. In certain cases, such infestations can cause severe food insecurity as in the case of desert locust upsurges in the Horn of Africa and Yemen in 2020-21 (FAO, 2022b).

In addition to the impact on food security, locusts can also devastate natural landscapes. Other implications on local populations can include local conflicts or migration due to shortage of food in severe locust upsurges. Furthermore, in certain cases, insecticide sprays can have implications on the health of local habitants.

Multi-hazard Context: The figure below summarises common interactions between locust upsurge and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring for locust upsurge. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

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Which institution(s) produce(s) Disaster Risk Data/Information?	The most efficiently functioning monitoring and early warning system is the desert locust monitoring system operated by FAO. Desert Locust Information Service (DLIS) and the three commissions (Western Region, Central Region and Southwest Asia) as well as the desert locust control committee (DLCC) (FAO, 2025a).
How is the Hazard Observed/Monitored/ Forecast?	The system utilizes a network of concerned countries that run surveys and share data over satellite tools with the Desert Locust Information Service (DLIS) operating since 1978 (FAO, 2025b) and housed at the headquarters of FAO, where the data is analysed together with geospatial and meteorological data. Analysis helps monitoring of the overall situation and production of forecasts and early warning for potential outbreaks to be shared with the concerned countries publicly.

Risk Management: Improvement of national capacities in preparedness, contingency planning, surveillance and rapid response is key for the prevention of such infestations and for mitigation of impacts. Likewise, international cooperation data and knowledge sharing is also key to address cases of transboundary infestations and upsurges. A good example of international collaboration has been experienced through the expansion of fall armyworms across Africa and Asia. FAO has developed and run a global initiative (FAO, 2020c).

Concerning the benefits of international collaboration and a solid response to emergencies, good lessons can be learnt from the locust upsurges in 2020-21 in the Horn of Africa and Yemen. The FAO-led response effort averted 4.5 million tonnes of crop losses, saved 900 million litres of milk production, and secured food for 41.5 million people (FAO, 2022a).

The main strategy for locust management, which has been promoted by the FAO for decades, relies on the so-called locust preventive control strategy. This is based on appropriate monitoring of locust habitats at key periods of their development in order to allow early detection of number increase and behaviour change, early warning, and early reaction (FAO, 2020d).

If well implemented, this approach facilitates a reduction in the occurrence and intensity of locust outbreaks and the prevention of their development into major upsurges or plagues.

Over decades, this strategy has been proven to be the most effective, making it possible to react before a significant increase in locust populations can occur. It results in: reduced damage to crops and rangelands and thus increased food security and improved livelihood of highly vulnerable rural communities; reduced negative impacts on human health and the environment (through reduced pesticide sprays); and lower financial costs.

For such transboundary plant pests, this strategy also needs to be coupled with global or regional cooperation. The FAO recommendations for dealing with locust upsurges in the Greater Horn of Africa Region include the following (FAO, 2020a):

- Ground surveillance and impact assessments: Facilitate ground surveillance, monitoring and continuous assessment in partnership with country governments and the Desert Locust Control Organization for Eastern Africa (DLCO-EA) with the objective of reinforcing region-wide early warning and response.
- Informing response: Continue to assess the situation through the FAO Desert Locust Information Service and provide early warning, forecasts and advice to affected countries and international partners.
- Control operations: Provide aerial and ground control operations support and enhance national preparedness capacity.
  - Ground control operations (hopper-stage locusts): procurement of chemical and bio-pesticides and equipment, storage, training, human and environmental safety, and disposal of chemical drums and containers.
  - Air control operations (adult-stage locusts): contracting planes, pesticide procurement, human and environmental safety, training, and disposal of chemical drums and containers.

On average, over the past 15 years, locust-affected areas as large as almost 4 million hectares have been treated annually in the Caucasus and Central Asia.

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Coordinating agency or organization

Food and Agriculture Organization (FAO); Desert Locust Control Committee (DLCC).

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BI0403 / BIOLOGICAL / Invasive Species

Invasive Species, Including Weeds

Definition

'Invasive species', also known as 'alien invasive species', are species whose introduction, establishment and spread into new areas threaten ecosystems, habitats or other species and cause social, economic or environmental harm, or harm to human health (FAO, 2007:82).

Reference

FAO, 2007. Invasive species. In: State of the World's Forests. Food and Agriculture Organization of the United Nations (FAO). www.fao.org/3/a-a0773e.pdf Accessed 10 October 2020.

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Annotations

Synonyms

Alien species, Alien invasive species, Invasive alien species.

Additional scientific description

Invasive species include species, subspecies or lower taxa of invertebrates, plants, microorganisms and vertebrates non-native (alien or exotic or non-indigenous) to a particular ecosystem and whose human-mediated or unintentional introduction and spread causes, or are likely to cause, socio-cultural, economic or environmental harm or harm to human health (FAO, 2007). In this description, plants encompass all types of weeds including parasitic. An alien species is a species, subspecies or lower taxon, introduced outside its natural past or present distribution; it includes any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce (UNEP, 2002).

Increasing international trade and human mobility, exacerbated by the impacts of climate change, have increased the introduction of plant and animal species into new areas where they have become invasive (FAO, 2020). These invasive species can have both direct nd indirect impacts on crop production and also damage natural habitats. Certain weeds pose additional threats to forests, water resources (such as aquatic weeds) or even the health of livestock and humans (poisonous weeds).

Estimates of the full costs of biological invasions are rare because of the difficulty in assessing the costs of impacts on biodiversity, ecosystem functions and human health, or other indirect costs such as the impact of control measures. The costs of invasive species to the forest sector have not been studied on a global scale. However, based on a study of six countries (Australia, Brazil, India, South Africa, the United Kingdom and the United States of America), it was estimated that as many as 480,000 alien species have been introduced in agriculture and forestry worldwide, with an annual cost of more than USD 1.4 trillion (FAO, 2007). Invasive plant and animal species are now considered one of the most important causes of biodiversity loss, especially in many island countries (CBD, 2009).

Concerning invasive weeds, the Convention on Biodiversity highlights that invasive plant species have been reported among inter alia seaweeds, trees, shrubs, vines, forbs and grasses. The indicative economic impacts of some invasive alien species are significant. For example, the direct impact of knapweed (*Centaurea spp.*) and leafy spurge (*Euphorbia esula*) on the economy of three US states is estimated at USD 40.5 million per year (direct costs) and USD 89 million as indirect costs (UNEP, 2001). Native to North America, common ragweed arrived in Europe in the 19th century and have since affected agriculture and human health. Large populations of this weed currently exist in many European countries being present in open spaces, waste grounds, and along roadsides. It is resistant to herbicides, and its long seed germination capacity (over 30 years) makes control difficult. It is known to reduce yields in the cultivation of maize, wheat, sunflowers, millet, peanuts, soy, beans and potatoes. It also plays a role as a secondary host for organisms that are harmful to cultivated plants (e.g., fungal pathogens that are harmful to sunflowers). Furthermore, its pollens are allergens for humans estimated to affect between 1 and 3.5 million people (Anses, 2024).

Preventing and reducing the harmful effects of invasive species requires an approach that incorporates biological, ecological and social sciences, economics, policy analysis and engineering. National efforts should include early warning systems, eradication and

control, as well as increased awareness and political leadership. Global, regional and bilateral efforts include standards and guidelines, monitoring and assessment, and information and action networks (FAO, 2007).

Numerous international and regional programmes and instruments, binding and non-binding, have been developed to address the problem of invasive species (FAO, 2007).

Different countries have different approaches – two of note are the Invasive Species Definition Clarification and Guidance prepared by the United States Department of Agriculture (USDA, 2006) and the Australian Weed Strategy (Australian Government, 2016).

Metrics and numeric limits

Not available.

Key relevant UN and regional convention / multilateral treaty

The Convention on Biological Diversity (1992) has three main objectives: the conservation of biological diversity, the sustainable use of the components of biological diversity, and the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources (United Nations, 1992). At the time of writing, there were 196 parties to the Convention on Biological Diversity.

The Convention on Biological Diversity (CBD) calls on its parties to 'prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats, or species' (Article 8[h]). The parties have adopted a series of 15 guiding principles to lead governments and organisations in developing effective strategies for minimising the spread and impact of invasive alien species (UNEP, 2002). The UN CBD introduced a commitment to endorse these principles in the 2011-2020 Global Biodiversity Strategy by adopting Aichi Target 9 (CBD, 2020).

European Commission (Environment) EU Regulation 1143/2014 on Invasive Alien Species (2015). Invasive alien species are animals and plants that are introduced accidentally or deliberately into a natural environment where they are not normally found, with serious negative consequences for their new environment. They represent a major threat to native plants and animals in Europe, causing damage worth billions of Euros to the European economy every year. As invasive alien species do not respect borders, coordinated action at the European level will be more effective than individual actions at the Member State level (European Commission, 2015).

The International Plant Protection Convention (1997) is an intergovernmental treaty signed by over 180 countries, aiming to protect the world's plant resources from the spread and introduction of pests and promote safe trade (FAO, 1999). The Convention introduced International Standards for Phytosanitary Measures (FAO, 2021) as its main tool to achieve its goals, making it the sole global standard-setting organisation for plant health. The International Plant Protection Convention (IPPC) is one of the 'Three Sisters' recognised by the World Trade Organization's (WTO) Sanitary and Phytosanitary Measures (SPS) Agreement (WTO, 1998), along with the Codex Alimentarius Commission for food safety standards and the World Organization for Animal Health (OIE) for animal health standards.

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). In the IPBES Regional Assessments (IPBES, 2018a) and Global Assessment Report (IPBES, 2019), invasive alien species were identified as one of the main direct drivers of biodiversity loss worldwide. The rapidly growing threat that invasive alien species pose to biodiversity, ecosystem services, sustainable development and human wellbeing is, however, generally poorly quantified and little understood by decision makers (IPBES, 2018b).

The International Union for Conservation of Nature (IUCN). The IUCN Species Survival Commission (SSC) Invasive Species Specialist Group maintains two global databases: the Global Invasive Species Database (GISD), which contains profiles of key invasive alien species, and the Global Register of Introduced and Invasive Alien Species (Pagad et al., 2018), which was developed with a mandate of the CBD and collates data on alien species in all taxonomic groups for all nations.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: An increase in the introduction and spread of invasive species or invasive alien species (insect pests, pathogens, microorganisms, vertebrates, plants and weeds) can result from increasing international trade, travel and the impacts of climate change.

Impacts: Economic, environmental, social and cultural impacts due to the loss of host trees, loss of crops and loss of biodiversity.

Insect pest infestations including invasive species may cause food security challenges especially if the staple food crops are affected. They can also result in market or price instability. The best-known example of such great impact was experienced in and around the 1840s when a deadly disease called potato late blight devastated the potato productions in Ireland causing the well-known great famine resulting in the death of over a million people (FAO-IPPC, 2017). Many outbreaks at smaller scales have been recorded in history. One recent example has been the rapid expansion of fall armyworms in Africa and Asia putting many countries in a difficult position to protect crops, particularly of smallholder farmers.

In addition to impact on plant production and food security, invasive species can also devastate natural landscapes. These can also include effects on water resources (aquatic weeds) and the potential health of animals and humans (poisonous weeds). Other

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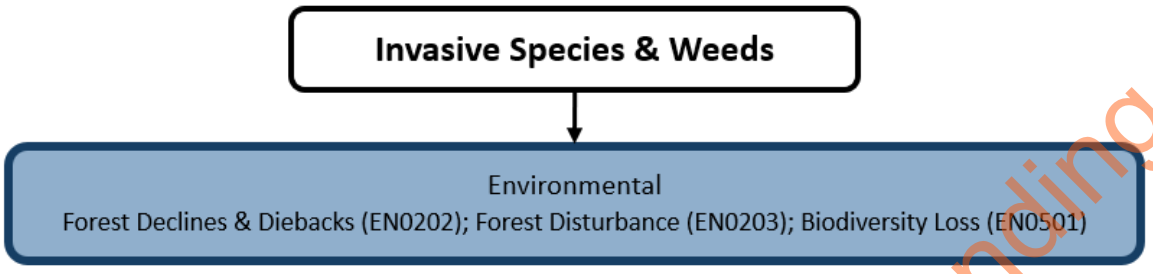
implications on local populations can include local conflicts or migration due to shortage in severe locust upsurges. Furthermore, in certain cases, insecticide sprays can have implications concerning the health of the local habitants.

Multi-hazard Context: The figure below summarises common interactions between invasive species & weeds and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring for invasive species and weeds. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	At global level, the pest reporting system of IPPC can be considered the most official resource for reports of the occurrence of quarantine plant pests including diseases (IPPC, 2025). Although in most cases such reports are deposited well after the establishment of a pest, these can be considered as early warning resources for other concerned countries. In this respect, the most efficiently functioning monitoring and early warning system is the desert locust monitoring system operated by FAO. The system is run by the Desert Locust Information Service (DLIS) and supported by three commissions (Western Region, Central Region and Southwest Asia) as well as the desert locust control committee (DLCC) (FAO, 2025a). In addition, there are numerous privately-run digital crowd-sourcing platforms such as Plant Village (Plant village, 2025).
How is the Hazard Observed/Monitored Forecast?	The IPPC pest outbreak and alert system (POARS) is based on official reporting of events by countries, while the desert locust monitoring system is based on reports of a network of concerned countries that run surveys and share data over satellite tools with the Desert Locust Information Service (DLIS), operating since 1978 (FAO, 2025b) and housed at the headquarters of FAO, where the data is analysed together with geospatial and meteorological data. Analysis helps monitoring the overall situation and production of forecasts and early warning for potential outbreaks to be shared with the concerned countries publicly. Other insects are monitored through official reports of countries, network communications, direct communications and public news.

Risk Management: This includes the establishment of early warning and early action activities; the implementation of phytosanitary standards in the agriculture and forestry sectors; and increased public awareness and community participation in early warning systems.

The Global Invasive Species Programme (GISP) was established in 1997 to address global threats caused by invasive species and to provide support to the implementation of Article 8(h) of the CBD. To increase awareness and provide policy advice, GISP has prepared the Global strategy on invasive alien species, which outlines ten strategic responses to the invasive species issue (FAO, 2007).

The GISD is a free, online searchable source of information about alien and invasive species that negatively impact biodiversity. It aims to increase public awareness about invasive species and to facilitate effective prevention and management activities by disseminating specialist knowledge and experience to a broad global audience. The GISD focuses on invasive alien species that threaten native biodiversity and natural areas and covers all taxonomic groups from microorganisms to animals and plants (GISD, no date).

The GISD is managed by the Invasive Species Specialist Group (ISSG) of the IUCN SSC. It was developed between 1998 and 2000 as part of the global initiative on invasive species led by the GISP (GISD, no date).

Because invasive species are addressed in different agreements and conventions (e.g., the Convention on International Trade in Endangered Species, IPPC and the World Trade Organization Agreement on the Application of Sanitary and Phytosanitary Measures), many countries have difficulty keeping up with the reporting requirements (FAO, 2007) In response, the UNEP World

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Conservation Monitoring Centre (UNEP-WCMC) has recently developed a set of issue-based modules summarizing country obligations under the CBD and other conventions, and in 2020 published a report on Building a Multidimensional Biodiversity Index (Soto-Navarro et al., 2020).

Early warning systems are most practical and effective at local and regional levels. The early warning systems targeting plant pests cover also invasive species. There are some early warning systems focusing on plant pests and diseases, particularly at regional levels, for example for North America (Meissner et al., 2015). International knowledge sharing and collaboration is critical in establishing early warning communications. At global level, the pest outbreak alert and reporting system (POARS) of IPPC can be considered the most official resource for reports of the occurrence of quarantine plant pests including invasive species, weeds and diseases (IPPC, 2025). Although such reports are deposited after the establishment of a pest, these can be considered as early warning resources for other concerned countries.

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Coordinating agency or organisation

Food and Agriculture Organization of the United Nations

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BI0501 / BIOLOGICAL / Infectious Disease (Plant)

Bacterial Plant Disease

Definition

A bacterial plant disease is the occurrence of plant diseases caused by bacterial microorganisms over large areas with significant impacts on crop and forest productivity or natural habitat (adapted from FAO, 2018).

Reference

FAO, 2018. The Impact of Disasters and Crises on Agriculture and Food Security: 2017. Food and Agriculture Organization of the United Nations (FAO). www.fao.org/3/i8656en/i8656en.pdf Accessed 12 February 2025.

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Annotations

Synonyms

Not applicable.

Additional scientific description

A bacterium is a single-celled, microscopic organism that lacks a nucleus (University of California, 2019). Plant diseases caused by bacterial pathogens place major constraints on crop and forest production and cause significant annual losses on a global scale (Sundin et al., 2016).

The Food and Agriculture Organization of the United Nations (FAO) estimates that each year, plant diseases cost the global economy around USD 220 billion (FAO, 2019).

Numerous bacterial diseases affect crop production in many countries and regions. These include fire blight in fruit trees, bacterial wilt in banana, bacterial blight in rice and crown gall in many perennial plants. In some cases, the epidemics caused by bacteria can cause significant economic burden on crops (FAO, 2018). An assessment to identify the key globally significant plant pathogenic bacteria indicated that the top ten include *Pseudomonas syringae* pathovars, *Ralstonia solanacearum*, *Agrobacterium tumefaciens*, *Xanthomonas oryzae* pv. *Oryzae*, *Xanthomonas campestris* pathovars, *Xanthomonas axonopodis* pathovars, *Erwinia amylovora*, *Xylella fastidiosa*, *Dickeya (dadantii* and *solani)* and *Pectobacterium carotovorum* (and *Pectobacterium atrosepticum*) (Mansfield et al., 2012)

When conditions are conducive, many of these species and many others can cause significant damage to plant production and natural landscape including forestry. For example, *Xylella fastidiosa* is a bacterial disease with many subspecies that in recent years has managed to establish itself in areas along the Mediterranean coast, where it is attacking economically important crops such as olive, citrus, stone fruits, grapevines and forest trees such as oak (FAO, 2020).

- In 2013, Italian researchers made a troubling discovery: one of the world's most destructive plant diseases, normally found in the Americas, had made its way to Italy's olive trees. With no known cure, the pathogen has already affected more than 10 million trees in the south-eastern tip of Italy. If not properly contained, it threatens to spread across the entire Mediterranean basin. The Italian government contracted national research institutes and the International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM) to survey and contain *X. fastidiosa*. Other Mediterranean countries are at great risk if the disease spreads further (FAO, 2020).
- The disease threatens to spread to the Near East and North Africa region. To help smallholders protect their crops and livelihoods, the FAO is supporting efforts in Near East and North African countries to raise awareness of the threat and implement technologies and techniques that can help prevent, detect and contain this deadly disease (FAO, 2020).
- Not only olive trees but also more than 500 other plant and forest tree species are hosts for the various strains of the bacterium. If not prevented, smallholders in the Near East and North African region could have their livelihoods devastated and national economies destabilized by the potential spread into the region. Because of these risks, the FAO

has launched a project to support Near East and North African countries in their efforts to prevent the introduction and spread of this disease (FAO, 2020).

Metrics and numeric limits

Not available.

Key relevant UN convention / multilateral treaty

The International Plant Protection Convention (1997) is an intergovernmental treaty signed by over 180 countries, aiming to protect the world's plant resources from the spread and introduction of pests, and promoting safe trade (FAO, 2011). The Convention introduced International Standards for Phytosanitary Measures (FAO, no date) as its main tool to achieve its goals, making it the sole global standard setting body for plant health. The IPPC is one of the 'Three Sisters' recognized by the World Trade Organization's (WTO) Sanitary and Phytosanitary Measures (SPS) Agreement, along with the Codex Alimentarius Commission for food safety standards and the World Organization for Animal Health (OIE) for animal health standards.

The International Standards for Phytosanitary Measures (ISPMs) are standards adopted by the Commission on Phytosanitary Measures (CPM), which is the governing body of the International Plant Protection Convention (IPPC). The first International Standard for Phytosanitary Measures (ISPM) was adopted in 1993 (FAO, 2024).

The Codex Alimentarius (FAO and WHO, no date a; FAO and WHO, no date b).

The WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) (WTO, 2025).

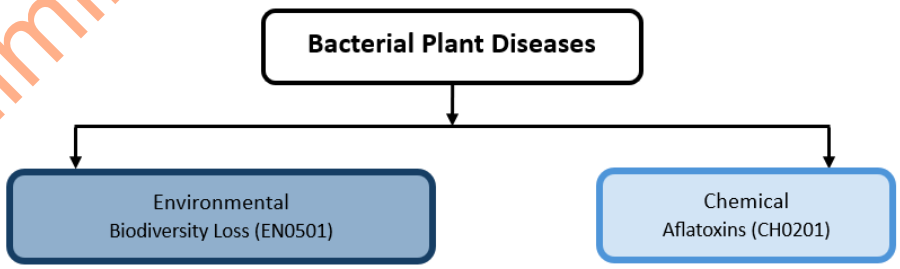
Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Although most bacteria existing in the soil and natural environments are beneficial, some cause significant diseases in plants under favourable conditions. Disruption of ecosystems, deficiencies in biosecurity and phytosanitary systems, and negligence of crop hygiene contribute to the build-up and spread of the inoculum of bacteria, causing substantive economic damage to crops and natural habitats. Prevention of spread is always easier than responding to outbreaks and control. Control of the diseases caused by bacteria is achieved by following the principles of sustainable plant production and integrated pest management practices.

Impact: Plant disease outbreaks may cause food security challenges especially if the staple food crops are affected. They can also result in market or price instability. One good example is the cacao swollen shoot virus causing some significant losses in West Africa in recent years.

Regarding the impact, numerous global estimations have been made mostly indicating a range of 20 - 30% of crop loss (Savary et al., 2019). It is estimated economic losses caused by plant diseases may reach USD 220 billion (Agrios, 2005). Bacterial diseases are important contributors to these losses.

Multi Hazard Context: The figure below summarises common interactions between bacterial plant diseases and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring for bacterial plant disease. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	There are several monitoring systems particularly at regional level, such as those for Europe (Peter et al, 2011) and North America (Meissner et al., 2015). At the global level, the pest reporting system of IPPC can be considered as the most official resource for reports of occurrence of quarantine plant pests including the diseases (IPPC, 2025).
How is the Hazard Observed/Monitored/Forecast?	Through official reports of countries; published scientific articles or network news

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Risk mitigation: The International Plant Protection Convention (IPPC) is the international forum providing space for intergovernmental discussions and negotiations on managing the risks resulting from spread of plant diseases (as well as other biological agents threatening plants). It provides facilities for establishment of international standards, capacity building and reporting for the purpose of minimizing risks of spread of these agents (IPPC, 2024).

Disease management approaches include focusing on diversified productions, use of pathogen-free certified planting materials, use of resistant varieties, regular surveillance, crop and forest hygiene and rapid containment and response at initial stages. Some bacteria are transmitted by insect vectors; thus, control of these vectors is important for disease management. Bacteria in agricultural environments can mutate and produce new strains that might be more aggressive than before. Therefore, monitoring and development of resistant varieties to emerging strains is critical for integrated management of the diseases caused.

Countries are expected to adhere the international standards and strengthen their phytosanitary capacity and biosecurity systems. Their capacity for preparedness, monitoring and rapid response should also be strengthened. In addition, international cooperation should be established or strengthened to address the regional or global challenges related to management of invasive and transboundary plant pests and disease, particularly those that are airborne.

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Coordinating agency or organisation

Food and Agriculture Organization of the United Nations (FAO).

Preliminary – Corrections Pending

BI0502 / BIOLOGICAL / Infectious Diseases (Plant)

Fungal Plant Diseases

Definition

Fungal plant disease is the occurrence of plant diseases caused by fungal agents over large areas with significant impacts on crop productivity or natural habitats (adapted from Arneson, 2001 and Moore et al., 2019).

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Preliminary – Corrections Pending

Annotations

Synonyms

Not identified.

Additional scientific description

Fungi are eukaryotic organisms that have a distinct nucleus and are classified as a separate kingdom, as are animalia and plantae. They include many important species causing plant diseases of local or global significance such as blights, wilts, rots, mildews, canker, smuts or rusts. The fungus structure largely consists of filamentous strands called mycelium and reproduces through various types of spores (CABI, no date).

Fungal diseases can occur in many forms on vegetative or reproductive organs of plants. The list of widely known diseases includes many types such as anthracnose; black knot; blight including chestnut blight and late blight; canker; clubroot; damping-off; Dutch elm disease; ergot; Fusarium wilt; leaf blister; mildew including downy mildew and powdery mildew; oak wilt; rot including basal rot, grey mould rot and heart rot; rust including wheat, soybean, pine blister, coffee and cedar-apple rust; scab including apple scab; smut including loose smut and corn smut; snow mould; sooty mould; and Verticillium wilt (Encyclopaedia Britannica, no date).

Collectively, fungi and fungal-like organisms (FLOs) cause plant diseases with over 8000 species shown to cause disease. Some of the world's great famines and periods of human suffering can be blamed on plant disease-causing fungi and FLOs (Williams et al., 2017).

The most known example of a disaster caused by a fungal pathogen is the potato late blight epidemic that caused the great famine in Ireland in the 1840s. This continues to be a good example of a single disease-causing devastating losses to potatoes worldwide (Suo-meng & Shao-qun, 2022). Another example is the wheat rust disease. It is well known that the continuing challenges of wheat rust diseases date back to ancient times when a specific festival `Robigalia` was organized in relation to protecting wheat crops from the rust disease (Bhavani et al., 2022).

In addition to being agents of pre-harvest and post-harvest diseases and rots, some fungi can produce highly toxic, hallucinogenic and carcinogenic chemicals that have not only affected the lives of millions historically but also continue to cause problems today. In 2006, dozens of dogs perished from food tainted with aflatoxin, a chemical produced by several Aspergillus species. These fungi can grow on many plants such as corn and produce toxins on the grain that not only affect the liver but are also one of the most carcinogenic substances known (Williams et al., 2017).

In addition to the harmful effects of fungal plant diseases, it should also be noted that Some fungi have beneficial roles in soil, but many are the major causal agents of plant diseases both during growth and in post-harvest processing. A wide range of fungicides are used to control fungi and to avoid production losses (FAO, 2017).

Metrics and numeric limits

Not identified.

Key relevant UN convention / multilateral treaty

The International Plant Protection Convention (1997) is an intergovernmental treaty signed by over 180 countries, aiming to protect the world's plant resources from the spread and introduction of pests and promote safe trade (FAO, 2011). The Convention develops and introduces International Standards for Phytosanitary Measures as its main tool to achieve its goals, making it the sole global standard-setting body for plant health. The IPPC is one of the 'Three Sisters' recognised by the World Trade Organization's (WTO) Sanitary and Phytosanitary Measures (SPS) Agreement, along with the Codex Alimentarius Commission for food safety standards and the World Organization for Animal Health (OIE) for animal health standards.

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Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Favourable climatic conditions, disruption of natural balance and deficiencies in crop and forest hygiene contribute to the build-up and spread of the inoculum of fungi regularly causing substantial damage to crops, forests and other natural habitats. Prevention of spread and outbreaks is always easier than responding to epidemics and control. Adopting the principles of sustainable plant production, sustainable forest management and integrated pest management practices are critical for the control of fungal plant diseases. Specific management methods include a focus on diversified production, the use of disease-resistant varieties, the use of pathogen-free certified planting materials, regular surveillance and rapid containment at initial stages all in an integrated manner.

Fungi mutate frequently and produce new strains that might be more aggressive. Therefore, continuous surveillance and development of resistant varieties to emerging strains is critical for integrated management of fungi and fungal-like organisms.

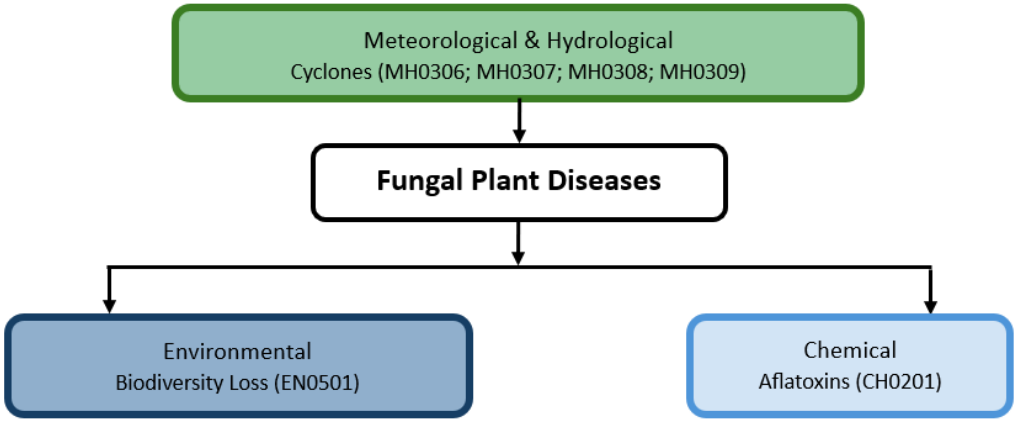
Impacts: Many fungal disease epidemics have affected crop production and forests in many countries and regions in world history. These include epidemics caused by potato blight, wheat rust diseases, chestnut blight, rice blast and banana Fusarium wilt. Estimation regarding economic losses for the whole group of fungal diseases is limited, but there are a few studies concerning the impact of specific diseases. For example, potato late blight causing the famine in Ireland in 1840s resulted in up to 10 billion USD in yield loss and management costs (Suo-meng & Shao-qun, 2022). It is estimated that wheat rust diseases cause global annual losses can be around 15 million tons valued at US$ 2.9 billion (Huerta-Espino et al., 2020).

Fungal plant disease outbreaks may cause food security challenges especially if the staple food crops are affected. They can also result in market or price instability. One good example of this is fluctuations of cocoa prices caused by the black pod disease of cocoa in Africa in 2024 (Africanews, 2024; J.P. Morgan, 2024). Similar effects occur in other crops too in different regions, but most remain unnoticed or not reflected sufficiently in the international fora. Plant disease outbreaks can also be a great concern for job losses for farm workers as in the case of outbreaks of banana Fusarium wilt TR4 (Altendorf, 2019).

In certain cases, fungal plant diseases can also affect animal and human health directly. In general, the issues related to pesticide residues and toxic substances in feed and food may escape attention, particularly in the developing world. There have been some critical cases in history in this respect. In 2006, dozens of dogs perished from food tainted with aflatoxin, a chemical produced by several Aspergillus species. These fungi can grow on many plants such as corn and produce toxins on the grain that not only affect the liver but is also one of the most carcinogenic substances known (Williams et al., 2017).

Multi-hazard Context: The figure below summarises common interactions between fungal plant diseases and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

Preliminary – Corrections Pending



Monitoring: The section and the table below offer an overview of monitoring for fungal plant diseases. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	There are several early warning systems particularly at the regional level, for example for Europe (Peter et al., 2011) and North America (Meissner et. Al. 2015). At global level, the pest reporting system of IPPC can be considered the most official resource for reports of the occurrence of quarantine plant pests including diseases (IPPC, 2025). Although such reports are deposited well after the establishment of a pest these can be considered as early warning resources for other concerned countries. At field level, a good global monitoring system has been developed for rust diseases of wheat (Global Rust Reference Centre, Aarhus University, 2025) providing monitoring and early warning, particularly for the new races.
How is the Hazard Observed/Monitored/Forecast?	Looking at disease reports from countries.

Risk Management: The missions of the International Plant Protection Convention (IPPC) cover fungal plant diseases as well as other pests and diseases. It forms an international forum providing space for intergovernmental discussions and negotiations on managing the risks resulting from the spread of plant diseases (as well as other biological agents threatening plants). It provides facilities for the establishment of international standards, capacity building and reporting for the purpose of minimizing risks of the spread of these agents.

Countries are expected to adhere to the international standards and strengthen their phytosanitary capacity and biosecurity systems. Their capacity for preparedness, monitoring and rapid response should also be strengthened. In addition, international cooperation should be established or strengthened to address the regional or global challenges related to the management of invasive and transboundary plant pests and diseases, particularly those that are airborne such as rust diseases of wheat and many types of blights and mildews of many crops.

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Coordinating agency or organisation

Food and Agriculture Organisation (FAO), the International Plant Protection Convention (IPPC) Secretariat.

Preliminary – Corrections Pending

BI0503 / BIOLOGICAL / Infectious Diseases (Plant)

Viral, Phytoplasma and Viroid Plant Disease Outbreaks

Definition

Viral, phytoplasma and viroid plant disease outbreaks refer to sudden occurrence of plant diseases caused by viruses, phytoplasma (syn. mycoplasma-like organisms) and viroids over large areas with significant impact on crop production or natural habitats (adapted from Nakashima & Murata, 1993; Hammond & Owens, 2006; FAO / IPPC, 2016; Rubio et al., 2020).

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Preliminary - Corrections Pending

Annotations

Synonyms

Phytoplasmas are often referred to as mycoplasma-like organisms (MLOs).

Additional scientific description

The terminology 'outbreak' is used if the disease occurs in a limited location or area, epidemic if it occurs in large areas and 'pandemic' if it occurs in multiple regions and at global scale.

Plant diseases are a major concern globally, given their potential economic impact on populations that rely on income from selling crops. The impact in places where there is increased food scarcity is of particular concern, as it exacerbates the insecurity and poverty felt by populations affected by these diseases. Along with fungi and bacteria, viruses, viroids and phytoplasmas (MLOs) are considered among the main disease agents causing significant crop losses, depending on crops and local conditions.

Plant viruses are small microorganisms without cell walls, containing nucleic acids surrounded by protein coats and replicating only inside living cells (Gergerich & Dolja, 2006). Phytoplasmas are obligate prokaryotic plant pathogens that do not possess cell wall, and they are pleiomorphic in profile, with a mean diameter of 200-800 nm (FAO & IPPC, 2016). The types affecting animals are usually called mycoplasmas. They lack cell wall and are bounded by unit membrane and have cytoplasm ribosomes and strands of nuclear material. Phytoplasmas are transmitted through insects that feed on plants, including plant hoppers and psyllids.

Viruses, phytoplasmas and viroids are very difficult to control as there is no pesticide available, and they are highly resistant to antibiotics and can be saprophytic or parasitic to plants (Britannica, 2019). Viroids are microorganisms that consist of a small

circular RNA molecule and are smaller than viruses and capable of causing certain plant diseases (Britannica, 2020).

The occurrence of phytoplasma in plants is a particularly difficult hazard to address, since they are 'the perfect parasite' and adapt to their host in a way that serves all their nutritional needs (Cleanroom Technology, 2008). While phytoplasmas generally do little harm, under conducive conditions they can provoke serious responses from their host causing illness and death in plants (Cleanroom Technology, 2008). Phytoplasma and Mycoplasma-Like organisms (MLOs) spread largely insect vectors such as leaf hoppers and are associated with more than 100 diseases (Arora & Sinha, 1988).

Metrics and numeric limits

Not identified.

Key relevant UN convention / multilateral treaty

The International Plant Protection Convention (IPPC) was approved by the Food and Agriculture Organization of the United Nations (FAO) on 6 December 1951, by Resolution No. 85/51. The IPPC is an intergovernmental treaty signed by over 180 countries, aiming to protect the world's plant resources from the spread and introduction of pests, and promote safe trade (FAO & IPPC, 1999). The Convention has introduced International Standards for Phytosanitary Measures (ISPMs) as its main tool to achieve its goals, making it the sole global standard-setting body (FAO & IPPC, 2021). The IPPC is one of the 'Three Sisters' recognised by the World Trade Organization's (WTO) Sanitary and Phytosanitary Measures (SPS) Agreement (WTO,1998), along with the Codex Alimentarius Commission for food safety standards, and the World Organization for Animal Health (OIE) for animal health standards.

Examples of hazard drivers, impacts, and risk management

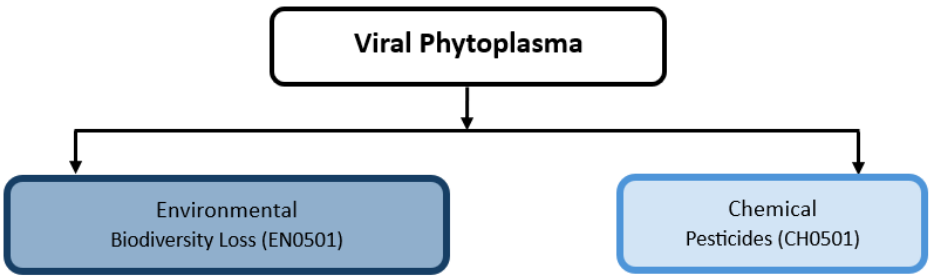
Hazard Drivers: Viruses are among the major causes of plant diseases in many plants, some being highly significant. Spread of viruses, phytoplasmas and viroids largely takes place through the movement of infected plant materials or through insect vectors such as aphids, white flies and mealybugs. Some nematodes and fungi are also reported to transmit viruses. Thus, integrated management approaches should consider the control of insect vectors as well as the use of virus-free planting materials.

Impact: Plant disease outbreaks may cause food security challenges, especially if the staple food crops are affected. Some of these pathogens can be present in plants in multiple forms and extend their damage. One good example is the viruses linked with the cocoa swollen shoot disease causing serious losses and market disruption in Ghana since the 1930s and recently. Involvement of at least six *badnavirus* in the infections made disease management very difficult and even had political consequences (Gymera et al., 2023).

Diseases of economic importance caused by viruses include tobacco mosaic virus, cassava viruses (mosaic virus and brown streak virus), banana bunchy top virus, tomato yellow leaf curl virus, cucumber mosaic virus, potato virus Y, plum pox virus and potato virus X, citrus tristeza virus and barley yellow dwarf virus (Gergerich & Dolja, 2006). These viral diseases cause serious losses to respective hosts under conducive conditions.

Major mycoplasma diseases include witches' broom of woody plants, X disease of peaches, coconut lethal decline, grapevine yellows, apple proliferation, while viroids causing significant diseases include potato spindle tuber viroid, citrus infected with *Citrus exocortis* viroid and avocado sunblotch viroids.

Multi-hazard Context: The figure below summarises common interactions between viral phytoplasma and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring for viral phytoplasma. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Preliminary – Corrections Pending

Which institution(s) produce(s) Disaster Risk Data/Information?	There are several early warning systems for plant pests and diseases including viruses, phytoplasmas and viroids, particularly at regional levels, for example for Europe (Peter et al., 2011) and North America (Meissner et al., 2015). At global level, the pest reporting system of IPPC can be considered the most official resource for reports of the occurrence of quarantine plant pests including diseases (IPPC, 2025). Although such reports are deposited well after the establishment of a pest these can be considered as early warning resources for other concerned countries.
How is the Hazard Observed/Monitored/Forecast?	Through official reports of countries; published scientific articles or network news.

Risk Management: The use of certified disease-free planting materials is critical as these pathogens can spread through planting materials. Thus, investments in strengthening the seed systems should be a priority, particularly in developing countries. In addition, to prevent local spread, control of the insect vectors should also be considered.

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Coordinating agency or organisation

Food and Agriculture Organization (FAO), International Plant Protection Convention (IPPC).

Preliminary – Corrections Pending

BI0601 / BIOLOGICAL / Other Biological Hazards

Antimicrobial Resistance

Preliminary – Corrections Pending

Definition

Antimicrobial-resistant (AMR) microorganisms are bacteria, fungi, viruses, or parasites that evolve to withstand antimicrobial treatments, including antibiotics, antifungals, antivirals, and antiparasitics. These resistant microorganisms, make infections harder to treat, increasing the risk of disease spread, severe illness, and mortality. AMR is a major global public health and food security challenge and is driven by the misuse and overuse of antimicrobials in human medicine, animal health, and plant production and protection, as well as environmental contamination (adapted from WHO, 2023 and FAO, 2025).

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Annotations

Synonyms

AMR, Superbugs.

Note: In some cases, the terms antibiotic resistance and antimicrobial resistance are used interchangeably which is incorrect. Antibiotic resistance has a narrower definition referring only to resistance to antibiotics which target bacteria while antimicrobial resistance relates to resistance or a broader range of microbes (bacteria, viruses, fungi, protozoa) and to a broader range of agents (antibiotics, antivirals, antifungals, antiprotozoals) (WHO, 2023).

Additional scientific description

Antimicrobial resistance (AMR) is a natural process that happens over time through genetic changes in pathogens. Its emergence and spread is accelerated by human activity, mainly the misuse and overuse of antimicrobials to treat, prevent or control infections in humans, animals and plants (WHO, 2023).

Antimicrobial medicines are the cornerstone of modern medicine. The emergence and spread of drug-resistant pathogens threatens our ability to treat common infections and to perform life-saving procedures including cancer chemotherapy and caesarean section, hip replacements, organ transplantation and other surgeries. In addition, drug-resistant infections impact the health of animals and plants, reduce productivity in farms, and threaten food security. AMR has significant costs for both health systems and national economies overall. For example, it creates the need for more expensive and intensive care, affects the productivity of patients or their caregivers through prolonged hospital stays, and harms agricultural productivity (WHO, 2023).

AMR is a problem for all countries at all income levels. Its spread does not recognize country borders. Contributing factors include lack of access to clean water, sanitation and hygiene (WASH) for both humans and animals; poor infection and disease prevention and control in homes, healthcare facilities and farms; poor access to quality and affordable vaccines, diagnostics and medicines;

lack of awareness and knowledge; and lack of enforcement of relevant legislation. People living in low-resource settings and vulnerable populations are especially impacted by both the drivers and consequences of AMR (WHO, 2023).

The economic losses due to AMR in agrifood systems could exceed USD100 trillion by 2050 due to reduced productivity, trade restrictions, and increased healthcare costs (Baudoin et al., 2021).

Examples of AMR in HIV, tuberculosis and malaria are summarised below:

- Over the past decade, the world has witnessed an unprecedented increase in the use of antiretroviral therapy (ART), which has saved the lives of tens of millions of people living with HIV/AIDS. At the end of 2021, 28.7 million people, out of an estimated 38.4 million people living with HIV, were receiving ART globally. Increased use of HIV medicines has been accompanied by the emergence of HIV drug resistance – the levels of which have steadily increased in recent years. HIV drug resistance is caused by changes in the genetic structure of HIV that affect the ability of drugs to block the replication of the virus. All current antiretroviral drugs, including newer classes, are at risk of becoming partly or fully inactive due to the emergence of drug-resistant virus strains (WHO, no date a).
- Multidrug-resistant TB (MDR-TB) is a form of TB disease caused by a strain of *M. tuberculosis* complex that is resistant to rifampicin and isoniazid. Globally, an estimated 410 000 people (95% UI: 370 000–450 000) developed multidrug- or rifampicin-resistant tuberculosis (MDR/RR-TB) in 2022. The treatment success rate for people diagnosed with MDR/RR-TB has steadily improved, but it remains alarmingly low. Globally, in 2020, the treatment success rate was 63%, up from 60% in 2019 and 50% in 2012 (WHO, 2024).
- The development of resistance to drugs poses one of the greatest threats to malaria control and results in increased malaria morbidity and mortality. Resistance to currently available antimalarial drugs has been confirmed in only two of the four human malaria parasite species, *Plasmodium falciparum* and *P. vivax* (CDC, 2024).

AMR is a complex problem that affects all of society and is driven by many interconnected factors. Single, isolated interventions have limited impact. Coordinated action is required to minimize the emergence and spread of antimicrobial resistance. All countries need national action plans on AMR to address the issue comprehensively. Greater innovation and investment are required in the research and development of new antimicrobial medicines, vaccines, and diagnostic tools (WHO, 2023).

Metrics and numeric limits

AMR is a growing global health crisis requiring multisectoral collaboration and sharing of information across multiple sectors, including a series of publications on metrics:

- In 2016, O'Neil and colleagues reported that their estimates project that, without effective intervention, AMR could result in 10 million deaths annually by 2050, surpassing mortality rates of major diseases such as cancer (O'Neil, 2016).
- Murray et al. (2022) estimated that bacterial AMR was directly responsible for 1.27 million deaths in 2019 and is associated with 4.95 million deaths globally, with the highest burden in low- and middle-income countries (Murray et al., 2022).
- Naghavi et al. (2024) reported, in their systematic analysis, that AMR-related mortality will continue to rise, with estimates of 1.91 million deaths directly attributable to AMR and 8.22 million associated deaths projected for 2050. The most affected regions will be South Asia, Latin America, and Sub-Saharan Africa, with the largest increase in AMR-related deaths occurring among individuals over 70 years old (Naghavi et al., 2024).
- Lewnard et al. (2024) reported that examining the AMR burden in low- and middle-income countries (LMICs) found that improving infection prevention and control (IPC) programs in LMIC healthcare settings could prevent at least 337,000 AMR-associated deaths annually (Lewnard et al., 2024).

The Food and Agriculture Organization of the United Nations (FAO) and WHO have published maximum residue limits in food products (FAO & WHO, 2018b, c).

Key relevant UN convention / multilateral treaty

The United Nations General Assembly adopted a Political Declaration on Antimicrobial Resistance during its seventy-ninth session on 7 October 2024. The full text of the declaration is available in the official UN document A/79/L.5.

WHO Global Action Plan on AMR. 2015 (WHO, 2015).

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Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Excessive and inappropriate use of antimicrobial agents in a range of sectors (human health, animal health, crop production), together with other aspects, such as lack of proper waste management or appropriate waste treatment, are key drivers in the exacerbation of antimicrobial resistance. Much attention has been focused on human exposure to antimicrobial-resistant pathogens in hospitals and similar settings and the implications for public health (FAO & WHO, 2018a).

The availability and use of antimicrobial drugs for human health as well as in terrestrial and aquatic animals and in crop production is essential to both health and productivity. Development and transmission of antimicrobial resistance through the food chain is complex with multiple contributing factors, hence addressing it using a coordinated, 'one health' response provides the most effective approach (FAO & WHO, 2018a).

The increase in antimicrobial resistance is a major global threat of increasing concern to human, animal and plant health. It also has implications for both food safety and food security and the economic wellbeing of millions of farming households (FAO & WHO, 2018a).

Ensuring universal access to high-quality water, sanitation, and hygiene (WASH) services could prevent 247,800 AMR-related deaths, while expanded vaccination programs could prevent 181,500 deaths by reducing both resistant infections and antibiotic consumption (Lewnard et al., 2024).

Impacts: Antimicrobial resistance (AMR) is one of the top global public health and development threats. It is estimated that bacterial AMR was directly responsible for 1.27 million global deaths in 2019 and contributed to 4.95 million deaths (WHO, 2023). Other impacts include:

- The misuse and overuse of antimicrobials in humans, animals and plants are the main drivers in the development of drug-resistant pathogens (WHO, 2023).
- AMR affects countries in all regions and at all income levels. Its drivers and consequences are exacerbated by poverty and inequality, and low- and middle-income countries are most affected (WHO, 2023).
- AMR puts many of the gains of modern medicine at risk. It makes infections harder to treat and makes other medical procedures and treatments – such as surgery, caesarean sections and cancer chemotherapy – much riskier (WHO, 2023).
- The world faces an antibiotics pipeline and access crisis. There is an inadequate research and development pipeline in the face of rising levels of resistance, and an urgent need for additional measures to ensure equitable access to new and existing vaccines, diagnostics and medicines (WHO, 2023).
- In addition to death and disability, AMR has significant economic costs. The World Bank estimates that AMR could result in US$ 1 trillion in additional healthcare costs by 2050, and US$ 1 trillion to US$ 3.4 trillion in gross domestic product (GDP) losses per year by 2030 (WHO, 2023).
- Priorities to address AMR in human health include preventing all infections, which may result in inappropriate use of antimicrobials; ensuring universal access to quality diagnosis and appropriate treatment of infections; and strategic information and innovation, for example, surveillance of AMR and antimicrobial consumption/use, and research and development for novel vaccines, diagnostics and medicines (WHO, 2023).

Multi-hazard Context: The figure below summarises common interactions between antimicrobial resistance and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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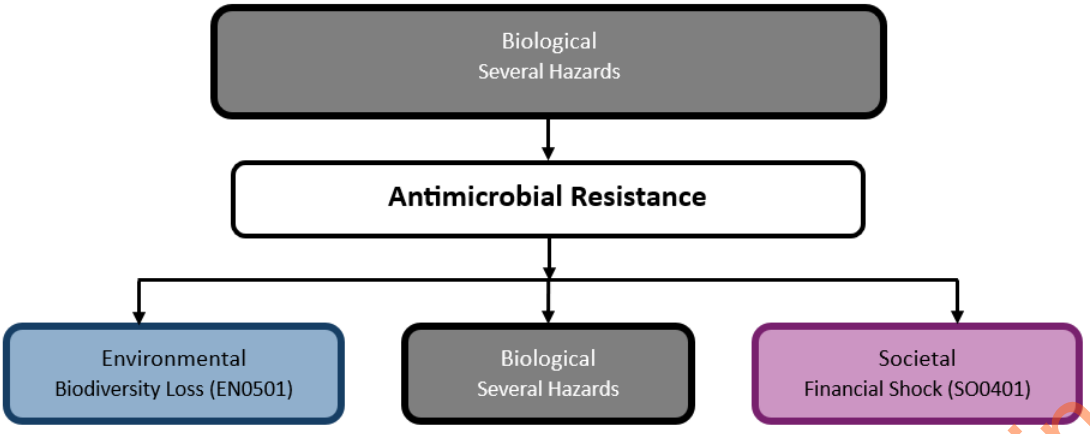

Monitoring: The section and the table below offer an overview of monitoring for antimicrobial resistance. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• Global Organizations: WHO (GLASS), FAO (InFARM), WOAH, UNEP • National Ministries: Ministries of Agriculture, Health, Food Safety, and Environment (responsible for AMR and AMU monitoring and policies) • Regional & National Surveillance Networks: e.g. European Centre for Disease Prevention and Control (ECDC) European Antimicrobial Resistance Surveillance Network (EARS)-Net), European Food Safety Authority (EFSA), Centers for Disease Control and Prevention (CDC) (National Antimicrobial Resistance Monitoring Systems -NARMS), China's Centre for Antimicrobial Resistance Surveillance System (CARSS), India's National Antimicrobial Resistance Surveillance Network (NARS)-Net, Africa Centres for Disease Control and Prevention (CDC) • Research & Academic Institutions: Fleming Fund, Wellcome Trust, Global Research on Antimicrobial Resistance (GRAM) Project (Oxford/Institute for Health Metrics and Evaluation (IHME)) • Genomic Surveillance & Databases: ResFinder, Comprehensive Antibiotic Resistance Database (CARD)
How is the Hazard Observed/Monitored/Forecast?	Global and national surveillance systems that track AMR (and AMU) in humans, animals, food, and the environment using laboratory-based testing, genomic sequencing, epidemiological studies, and risk modelling to detect trends, assess risks, and predict future resistance patterns.

AMR early warning systems have lead times ranging from months to years, depending on the surveillance approach. Laboratory-based monitoring (phenotypic and genomic testing) can detect emerging resistance within weeks to months, while AMR epidemiological modelling and AMU trend analysis help forecast resistance spread over months to years. Environmental and One Health surveillance provide early indicators of resistance evolution, but their lead times depend on data integration and sampling frequency. Unlike acute disease outbreaks, AMR trends develop gradually, requiring continuous monitoring to enable timely policy and stewardship interventions (Ho et al, 2025).

Risk Management: The Quadripartite consisting of the World Health Organization (WHO), the Food and Agriculture Organization of the United Nations (FAO), the World Organization for Animal Health (WOAH), and the United Nations Environment Programme (UNEP) collaborate through a 'One Health' approach to promote good practices to prevent and mitigate the emergence and spread of AMR through complementary strategies which include:

- ***One Health approach***: AMR is a complex problem that requires sector-specific actions in the human health, food production, animal and environmental sectors, and a coordinated approach across these sectors. One Health refers to an integrated, unifying approach that aims to achieve optimal and sustainable health outcomes for people, animals and ecosystems. It recognizes that the health of humans, domestic and wild animals, plants and the wider environment are closely linked and interdependent. The One Health approach to preventing and controlling AMR brings together stakeholders from relevant sectors to communicate and work together in the design, implementation and monitoring of programmes, policies, legislation and research to mitigate AMR and attain better health and economic outcomes (WHO, no date a).
- ***Global Action Plan (GAP) on Antimicrobial Resistance*** (GAP-AMR) addresses AMR globally and was adopted in 2015 by the World Health Assembly, emphasizing five strategic objectives: improving awareness and understanding of AMR, strengthening knowledge through surveillance and research, reducing the incidence of infection, optimizing the use of antimicrobial agents, and developing the economic case for sustainable investment. A political declaration endorsed by Heads of State at the United Nations General Assembly in New York in September 2016 reinforced global commitment to addressing AMR through

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coordinated multisectoral actions across human health, animal health, plant health, and the environment (UNGA, 2024). This commitment was further strengthened by the 2024 Political Declaration on AMR, which emphasized the urgent need for accelerated actions, increased investments, and stronger international collaboration to mitigate AMR's impact on global health, food security, and sustainable development (UNGA, 2024).

- ***Quadripartite Joint Secretariat on Antimicrobial Resistance***: To coordinate the One Health global response to AMR, WHO works closely with the Food and Agriculture Organization of the United Nations (FAO), the UN Environment Programme (UNEP) and the World Organisation for Animal Health (WOAH). The 4 organizations (FAO, UNEP, WHO and WOAH) are known as the Quadripartite Organizations. A quadripartite joint secretariat is hosted by WHO to drive multi-stakeholder engagement in AMR. This has supported the establishment of the Global Leaders Group on AMR, which began its work in November 2020, and the Multi-Stakeholder Partnership Platform, which was launched in November 2022, and several technical working groups (FAO, WOAH, WHO, UNEP, 2022).

As a Quadripartite, WHO, FAO, WOAH, and UNEP jointly implement initiatives such as the AMR Multi-Partner Trust Fund, which mobilizes resources to support national AMR action plans, and the One Health Joint Plan of Action, which fosters cross-sectoral coordination. Additionally, global governance mechanisms like the Global Leaders Group on AMR ensure policy coherence and stakeholder engagement at all levels, Each quadripartite organisation contributes as follows:

- WHO leads multiple initiatives to combat AMR, prioritizing improved antimicrobial stewardship programs and enhancing monitoring and surveillance of AMR and antimicrobial use (AMU) in humans through the Global Antimicrobial Resistance Surveillance System (GLASS) (WHO, no date b), The organization also fosters research and development of new antimicrobial treatments through the Global Antibiotic Research and Development Partnership (GARDP) (WHO, no date c).
- FAO is strongly focused on capacity building for good practices, prudent antimicrobial use, strengthening regulatory frameworks and developing robust AMR and AMU surveillance systems in food and agriculture through the recently launched the “Reduce the Need of Antimicrobials in Farms” (RENOFARM) initiative for sustainable livestock transformation (FAO, no date a)., and the International FAO AMR Monitoring (InFARM) system (FAO, no date b) It has also developed capacity building tools such as the FAO Assessment Tool for Laboratories and AMR Surveillance Systems (FAO-ATLASS) to improve laboratory capacities worldwide (FAO, no date c), FAO supports the implementation of good practices in livestock, aquaculture, and plant production and protection to mitigate AMR risks (FAO, 2021).
- WOAH contributes by strengthening AMU data collection and monitoring in animal health through the WOAH ANIMUSE database (WOAH, no date). It also supports national veterinary legislation and capacity-building for prudent antimicrobial use in veterinary medicine.
- UNEP plays a key role in addressing the environmental dimensions of AMR, conducting research on AMR contamination in water, soil, and waste management, and strengthening policies to reduce AMR pollutants from pharmaceuticals and agricultural runoff (UNEP, no date).

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Coordinating agency or organisation

World Health Organization (WHO), the Food and Agriculture Organization of the United Nations (FAO), the World Organization for Animal Health (WOAH), and the United Nations Environment Programme (UNEP)

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BI0602 / BIOLOGICAL / Other Biological Hazards

Biological Agents (CBRNE)

Definition

Biological and toxin agents are either microorganisms like viruses, bacteria or fungi, or toxic substances produced by living organisms that are produced and released deliberately to cause disease and death in humans, animals or plants (WHO no date).

Biological agents include bacteria, viruses, fungi, other microorganisms and their associated toxins. They have the ability to adversely affect human health in a variety of ways, ranging from relatively mild, allergic reactions to serious medical conditions–even death. In some forms, biological agents can also be weaponized for use in bioterrorism or other crimes (adapted from US OSHA, no date)

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Annotations

Synonyms

Biological weapons.

Additional scientific description

Biological agents like anthrax, botulinum toxin and plague can pose a difficult public health challenge causing large numbers of deaths in a short amount of time. Biological agents, which are capable of secondary transmission, can lead to epidemics. An attack involving a biological agent may mimic a natural event, which may complicate the public health assessment and response. In case of war and conflict, high-threat pathogens laboratories can be targeted, which might lead to serious public health consequences (WHO, no date).

Biological weapons form a subset of a larger class of weapons sometimes referred to as unconventional weapons or weapons of mass destruction, which also includes chemical, nuclear and radiological weapons. The use of biological agents is a serious concern, and the risk of using these agents in a terrorist attack is thought to be increasing (WHO, no date).

WHO focuses on the possible public health consequences of an incident due to a biological agent, regardless of whether it is characterized as a deliberate act or a naturally occurring event (WHO, no date).

Bioterrorism involves intentionally releasing viruses, bacteria, or toxins to harm people, livestock, or crops. Bacillus anthracis, the cause of anthrax, is a likely agent for such attacks (CDC, 2025). For example, an anthrax attack can take various forms, such as through mailed letters or contaminated food or water. It could be released into the air, which can lead to anthrax spores being spread by wind or by being carried on people's belongings. Even a small amount of anthrax can infect many people (CDC, 2025).

As an example, Jernigan et al (2002) reported that in October 2001, the first inhalational anthrax case in the United States since 1976 was identified in a media company worker in Florida. A national investigation was initiated to identify additional cases and determine possible exposures to Bacillus anthracis. Surveillance was enhanced through health-care facilities, laboratories, and other means to identify cases, which were defined as clinically compatible illnesses with laboratory-confirmed B. anthracis infection. From October 4 to November 20, 2001, 22 cases of anthrax (11 inhalational, 11 cutaneous) were identified; 5 of the inhalational cases were fatal.

Twenty (91%) case patients were either mail handlers or were exposed to worksites where contaminated mail was processed or received. B. anthracis isolates from four powder-containing envelopes, 17 specimens from patients, and 106 environmental samples were indistinguishable by molecular subtyping. Illness and death occurred not only at targeted worksites but also along the path of mail and in other settings. Continued vigilance for cases is needed among health-care providers and members of the public health and law enforcement communities (Jernigan et al., 2002).

Metrics and numeric limits

Assessment of treaty compliance is partly based on the understanding and application of a so-called General Purpose Criterion (GPC) as it pertains to 'hostile uses' or in 'armed conflict' (Article I). Since the Chemical Weapons Convention (CWC) covers toxins, the international legal prohibition against biological warfare should also be understood to include the 'method of warfare' (UNODA, 1972).

Grey areas exist with respect to formulations and applications that differ from those developed by historical state biological weapons programmes, including for behaviour modification or for use in situations outside the traditional understanding of state-to-state armed conflict such as peacekeeping or counter-terrorism operations.

Key relevant UN convention / multilateral treaty

The General Purpose Criterion, which is embodied in the Biological and Toxin Weapons Convention's definition of prohibited activities, is the mechanism that ensures the Convention's prohibitions remain comprehensive in scope, including in terms of scientific and technological developments (UNODA, 1972).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Biological agents are devices or agents used or intended to be used in a deliberate attempt to disseminate disease-producing organisms or toxins using aerosol, food, water, or insect vectors. Their mechanism of action tends to be broadly through infection or intoxication noting the relative ease with which the agents may be deployed and their potentially devastating effects.

Impacts: If a biological attack goes unnoticed until doctors observe unusual illness patterns in emergency rooms and alert public health authorities, it could lead to many severe illnesses and deaths (CDC, 2025).

Multi-hazard Context: depends on the biological and toxin agents that are released such as viruses, bacteria or fungi, or toxic substances produced by living organisms that are produced and released deliberately to cause disease and death in humans, animals or plants (WHO, no date).

Monitoring: WHO supports countries to conduct all-hazards strategic risk assessment in the contexts of health emergencies and disasters, which results in the development of a country's risk profile. Empowered with the country risk profile, inclusive of a seasonal risk calendar, countries can anticipate potential emergencies before they occur to trigger early alerts and inform early actions (WHO, 2021).

WHO's Early Warning, Alert and Response System (EWARS) has been designed to improve disease outbreak detection in emergency settings, such as in countries in conflict or following a natural disaster. It is a simple and cost-effective way to rapidly set up a disease surveillance system. EWARS is deployed during an emergency as an adjunct to the national disease surveillance system. WHO works with Ministries of Health and health sector partners to train local health workers to use the system. After the emergency, EWARSs should re-integrate back into the national system (WHO, no date c).

WHO's global alert and response activities and the Global Outbreak Alert and Response Network (GOARN) represent a major pillar of global health security aimed at the detection, verification and containment of epidemics. In the event of the intentional release of a biological agent, these activities would be vital to effective international containment efforts (WHO, no date).

Risk Management: WHO is committed to saving lives and reducing suffering during times of crisis – whether caused by conflict, disease outbreak or a disaster. WHO's Health Emergencies Programme is committed to working with Member States and other stakeholders so that suffering and death in crises are minimized and systems are protected and repaired (WHO, no date b).

WHO's Health Emergencies Programme provides the following services to countries:

- support of the assessment of country health emergency preparedness and development of national plans to address critical capacity gaps;
- development of strategies and capacities to prevent and control high-threat infectious hazards; and
- monitoring of new and ongoing public health events to assess, communicate and recommend action for public health risks (WHO, no date b).

In addition, WHO will work with countries and partners to:

- ensure readiness to diminish public health risks in countries with high vulnerability; and

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- provide life-saving health services to affected populations in countries with ongoing emergencies (WHO, no date b).

When a Member State is concerned about biological agents and wants to be better prepared, WHO advises strengthening public health surveillance and response activities, with an emphasis on:

- more effective national surveillance of outbreaks of illness, including alert and response systems at all levels that can detect diseases that may be deliberately caused;
- improved biosafety and biosecurity throughout the health sector;
- better communication between multiple sectors, including public health, animal health, water supply, food safety, poison control, civil protection, law enforcement, and security services;
- improved assessments of vulnerability, and effective communication about risks and threats to both professionals and the public;
- preparation for handling the psychosocial consequences of the deliberate use of pathogens to cause harm; and
- contingency plans for an enhanced response capacity by all sectors (WHO, no date).

With the occurrence of a potential, suspected or confirmed deliberate biological event, WHO would, upon the invitation of the affected Member State(s), work closely with the Member State government(s), other UN agencies, and other international partners as appropriate, support the event response, and assess and mitigate the public health consequences (WHO, no date). These activities could include:

- working with relevant international or national organizations to better characterize the nature, scope and impact of the event;
- facilitating the public health investigation of the event, including referral to appropriate laboratories for confirmation and characterization of the pathogen;
- offering targeted training to public health responders;
- facilitating the identification and acquisition of necessary materials (such as personal protective equipment) appropriate to the event;
- supporting the continued delivery of essential health services; and
- developing guidance material specific to the pathogen or toxin in question (WHO, no date).

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

BI0603 / BIOLOGICAL / Fisheries and Aquaculture

Harmful Algal Blooms

Definition

Harmful algal blooms result from noxious and/or toxic algae that cause direct and indirect negative impacts on aquatic ecosystems, coastal resources, and human health (Kudela et al., 2015).

Reference

Kudela, R., E. Berdalet, S. Bernard, M. Burford, L. Fernand, S. Lu, S. Roy, G. Usup, P. Tester, R. Magnien, D. Anderson, A. Cembella, M. Chinain, G. Hallegraeff, B. Reguera, A. Zingone, H. Enevoldsen and E. Urban, 2015. Harmful Algal Blooms. A scientific summary for policy makers. https://unesdoc.unesco.org/ark:/48223/pf0000233419 Accessed 12 February 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

HABs.

Additional scientific description

Harmful algal blooms (HABs) are present in nearly all aquatic environments (freshwater, brackish, marine), as naturally occurring phenomena (Kudela et al., 2015).

Many HABs are increasing in severity, frequency, and biogeographical range. Causes are complex, but in some cases can be attributed to climate change and human impacts, including eutrophication, habitat modification, and human-mediated introduction of exogenous species (Kudela et al., 2015).

Photosynthetic algae support healthy aquatic ecosystems and form the base of the food web, fixing carbon and producing oxygen. Under certain circumstances, some species can form high-biomass and/or toxic proliferation of cells (or 'blooms'), thereby causing harm to aquatic ecosystems, including plants and animals, and to humans via direct exposure to water-borne toxins or toxic seafood consumption. Ecosystem damage by high-biomass blooms may include disruption of food webs, fish-killing by gill damage, or contribution to low oxygen 'dead zones' after bloom degradation. Some HAB species also produce potent natural chemicals (toxins) that can persist in the water or enter the food web, leading to illness or death of aquatic animals and/or human seafood consumers (Kudela et al., 2015).

Even non-toxic algal blooms can have devastating impacts when they lead to kills of fish and invertebrates by generating anoxic conditions. Some algal species, although non-toxic to humans, can produce exudates that cause damage to the delicate gill tissues of fish (such as the raphidophytes *Chattonella*, *Heterosigma*, and dinoflagellates *Karenia*, *Karlodinium*). Aquaculture stocks (caged fish, molluscs, crustaceans) are trapped and, thus, can suffer devastating mortalities, which could lead to economic and food losses and may eventually become a food security issue (FAO & WHO, 2020).

Of greatest concern to human society are algal species that produce potent neurotoxins that can find their way through shellfish and fish to human consumers, where they cause a variety of gastrointestinal and neurological illnesses (FAO, 2012).

Metrics and numeric limits

Various systems are available and used to assist in determining HAB toxicity. These include:

- National Centers for Coastal Ocean Science (NCCOS) of the US National Oceanic and Atmospheric Administration (NOAA) developed the Algal Bloom Monitoring System to routinely deliver near real-time products for use in locating, monitoring and quantifying algal blooms in coastal and lake regions of the U.S. This application delivers a suite of bloom detection products in the form of geographic-based images (NCCOS, no date).
- The Centre for Environment, Fisheries and Aquaculture Science is an executive agency of the United Kingdom government's Department for Environment, Food and Rural Affairs. CEFAS runs a Harmful Algal Blooms (HABS) Surveillance Programmes and Monitoring aims to identify algae in blooms that may produce potent biotoxins which can accumulate in filter-feeding bivalve molluscs and sometimes in other shellfish, such as grazing gastropods. The results of the FSA/FSS biotoxin and phytoplankton monitoring programmes are published weekly (CEFAS, no date).

Key relevant UN convention / multilateral treaty

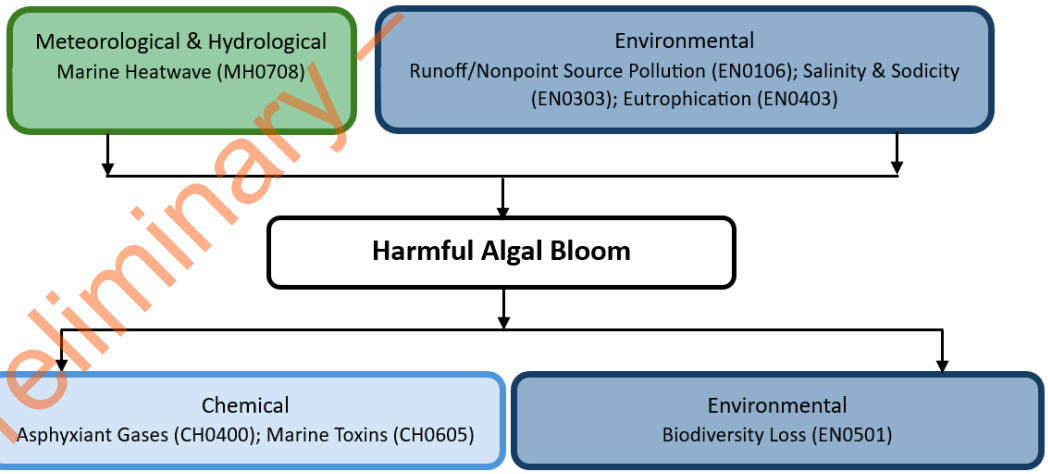
Not identified

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: It is difficult to predict when a HAB will develop. Climatic and environmental conditions such as changes in salinity, rising water temperature, and increased nutrient levels and sunlight can influence population growth for HAB species. In some cases, these changes can be attributed to human impacts, including habitat modification, and human-mediated introduction of exogenous species (NOAA, 2016).

Impacts: Many islands and countries in arid regions, where freshwater resources are limited, are increasingly dependent on desalination to provide water to rapidly growing coastal populations and to meet the social and economic demands that underpin development in those areas. Evidence is now showing that HABs pose a threat to the desalination industry and to water security in those areas. Studying HABs in the vicinity of desalination plants is an emerging science because there is limited information on the potential problems that toxic blooms may pose (UNESCO, 2015).

Multi-hazard Context: The figure below summarises common interactions between harmful algal blooms and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Preliminary – Corrections Pending

Monitoring: The section and the table below offer an overview of monitoring for harmful algal blooms. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Centres that develop and implement monitoring systems can operate under different competent authorities covering both food safety control and environment.

How is the Hazard Observed/Monitored/Forecast?	Monitoring systems and early warning systems for marine biotoxins and HABs

Risk Management: Harmful algal blooms are recognised as one facet of complex ecosystem interactions with human society. Research, monitoring, and management of HABs must be closely integrated with policy decisions that affect the global oceans (Kudela et al., 2015). The Intergovernmental Oceanographic Commission (IOC-UNESCO) has been a driver in defining the international research agenda on HABs and their impacts and is now also addressing how to provide solutions applicable to desalination plants (UNESCO, 2015).

There is no plan and no realistic possibility of eliminating HABs and/or their dependent consequences. Nevertheless, decades of research and monitoring have improved the understanding of HAB events, leading to better monitoring and prediction strategies (Kudela et al., 2015).

Harmful algal blooms are a worldwide phenomenon requiring an international understanding leading ultimately to local and regional solutions. Continued progress in research, management, mitigation, and prediction of HABs benefits from international coordination. In this spirit, the international community has developed programmes sponsored by the IOC and Scientific Committee on Oceanic Research (SCOR) to coordinate international HAB research, framework activities, and capacity building (Kudela et al., 2015).

New technologies and approaches to monitoring, control and management of HABs are now available, highlighting molecular probes for cell detection, rapid and sensitive toxin assays, remote sensing detection and tracking of blooms, bloom control and mitigation strategies, and the use of large-scale physical/biological models to analyse past blooms and forecast future events (Anderson, 2009).

New initiatives, such as GlobalHAB sponsored by IOC and SCOR, will continue to provide the mechanisms to further understand, predict, and mitigate HABs. Research, management, and mitigation efforts directed towards HABs must be coordinated with other local, national, and international efforts focused on food and water security, human and ecosystem health, ocean observing systems, and climate change (Kudela et al., 2015).

The establishment of national monitoring programmes for marine biotoxins and their source organisms (HABs) is needed. These programmes require continuous update to include new and emerging toxins when necessary and for harvesting area management.

Preliminary – Corrections Pending

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Coordinating agency or organisation

Food and Agriculture Organization of the United Nations.

Preliminary – Corrections Pending

BI0604 / BIOLOGICAL / Human-Animal Interaction

Human-Wildlife Conflict

Definition

Human-wildlife conflict is defined as struggles that emerge when the presence or behaviour of wildlife poses an actual or perceived, direct and recurring threat to human interests or needs, leading to disagreements between groups of people and negative impacts on people and/or wildlife (IUCN SSC, 2022)

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Preliminary – Corrections Pending

Annotations

Synonyms

Animal-human interaction, Human-wildlife interaction, HWC.

Additional scientific description

Wildlife can threaten people's safety and livelihoods, which can lead to conflicts between groups of people over how to resolve the situation; experts call this 'human-wildlife conflict' (ICUN, 2022). Wildlife management also entails dealing with human-wildlife conflicts, particularly when there are no fences around protected areas in order to allow for the migration of wildlife species (FAO & UNEP, 2020). Human-wildlife conflict affects most large carnivores, as well as many other species groups including, but not limited to, elephants, pigs, deer, primates, sharks, seals, birds of prey, crocodiles, rhinos, and otters (IUCN SSC, 2024).

Human-wildlife conflicts are becoming more frequent, serious and widespread as human populations grow and habitats are lost (ICUN, 2022). Human-wildlife conflict is a serious global threat to sustainable development, food security, conservation, and health – a concern that is negatively affecting both people and wildlife and hindering the achievement of many of the Sustainable Development Goals (SDGs) (IISD, 2021). Impacts on the population of wild animals that are being culled by the affected local populations can have significant consequences (Mozer & Prost, 2023).

In general, the consequences of human-wildlife conflict include destruction of crops, reduced farm productivity, competition for grazing lands and water, livestock predation, injury and death to farmers, damage to infrastructure and increased risk of disease transmission from wildlife to livestock (FAO, 2023a).

Human-wildlife conflict often triggers negative sentiments towards conservation, especially when protected areas are being established or expanded (FAO and UNEP, 2020). With specific reference to forests, a high density of large ungulates, for example, deer, can cause severe damage to the forest and can threaten regeneration by trampling or browsing small trees, rubbing against trees or stripping tree bark (FAO, 2016).

The interface between humans, domestic animals, and wild animals can also be a source of disease, impacting local and global public health and the social and economic well-being of communities and the world population. Diseases transmissible from animals to humans through direct contact or through food, water, and the environment, are commonly referred to as 'zoonoses' It recognizes that the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent (WHO no date a).

While health, food, water, energy and environment are all wider topics with sector-specific concerns, the collaboration across sectors and disciplines contributes to protecting health, addressing health challenges such as the emergence of infectious diseases, antimicrobial resistance, and food safety and promoting the health and integrity of ecosystems. One Health is an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals and ecosystems (WHO, no date a)

By linking humans, animals and the environment, One Health can help to address the full spectrum of disease control – from prevention to detection, preparedness, response and management – and contribute to global health security. The approach can be applied at the community, subnational, national, regional and global levels, and relies on shared and effective governance, communication, collaboration and coordination. Having the One Health approach in place makes it easier for people to better understand the co-benefits, risks, trade-offs and opportunities to advance equitable and holistic solutions (WHO, no date a).

Metrics and numeric limits

Some 60% of emerging infectious diseases that are reported globally come from animals, both wild and domestic. Over 30 new human pathogens have been detected in the last 3 decades, 75% of which have originated in animals (WHO, 2023).

Key relevant UN convention / multilateral treaty

Convention on Biodiversity Post-2020 Global Biodiversity Framework of 2022. The vision of the framework is a world living in harmony with nature, where "By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people" (CBD, 2022).

UNEP collaborates with biodiversity-related conventions and scientific bodies. The Convention on Biological Diversity is an international, legally binding treaty covering biodiversity at all levels: ecosystems, species and genetic resources. It also covers biotechnology through the Cartagena Protocol on Biosafety. The Convention recognizes that biological diversity is about more than plants, animals and micro-organisms and their ecosystems. It is about people and the need for food security, medicines, fresh air and water, shelter, and a clean and healthy environment in which to live (CBD, 2022).

UNEP also works closely with and hosts the Secretariats of

- the Convention on the Conservation of Migratory Species of Wild Animals (CMS, 1979)
- the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 1963)
- the Inter-governmental Panel on Biodiversity and Ecosystem Services (IPBES). https://www.ipbes.net/about

Quadripartite Memorandum of Understanding (MoU) signed for a new era of One Health collaboration (2022) The four international agencies, the Food and Agriculture Organization of the United Nations (FAO), the World Organisation for Animal Health (OIE), the UN Environment Programme (UNEP) and the World Health Organization (WHO), have signed a groundbreaking agreement to strengthen cooperation to sustainably balance and optimize the health of humans, animals, plants and the environment. (WHO, 2022).

Examples of hazard drivers, impacts, and risk management

Hazard Driver: Human-wildlife conflict often severely impacts the livelihoods, security and wellbeing of the people who support wider conservation goals, and affects many nations trying to align with, and benefit from, conservation and development programmes (IUCN SSC, no date).

Impacts: Conflicts between humans and wildlife, and between humans over wildlife, have occurred since the dawn of humanity. However, in many regions these conflicts have intensified over recent decades as a result of human population growth and the related expansion of agricultural and industrial activities. Conflicts have also arisen due to the growth of some wildlife populations and the presence of certain species (e.g. red fox, wild boar) in urban environments,1as well as a recurrent inability of institutions to manage such conflicts effectively. Climate change is exacerbating these conflicts through, for example, increased competition for water and habitats (FAO, 2023b).

Additionally, 75% of emerging pathogens are of zoonotic nature. Progress towards global health security requires a greater focus on the interface between humans and animals and a strong collaboration between the human health and the animal health sectors (WHO, no date b).

Multi-hazard Context: The figure below summarises common interactions between human-wildlife conflict and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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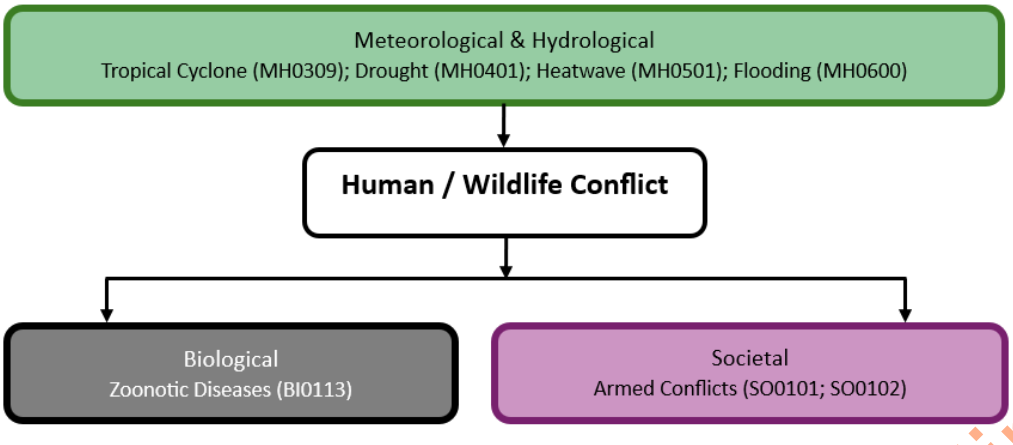

Monitoring: Surveillance that monitors risks and helps identify patterns across these many areas is needed. In addition, new research should integrate the impact of these different fields, particularly on the drivers that lead to crises. For example, to implement One Health, major structural changes are required to integrate the human, animal and environmental health fields and support multi-sectoral communication, collaboration, coordination, and capacity strengthening (WHO, 2023).

Risk Management: As many countries tackle this multi-faceted challenge, the issue of human-wildlife conflict is starting to be considered in national policy and strategies for wildlife, development, and poverty alleviation. However, there is a need to improve the sharing and transfer of knowledge, adopt a more inclusive and interdisciplinary approach, and greatly increase cross-sectoral collaboration among forestry, wildlife, agriculture, livestock, and other relevant sectors at the national level (FAO, 2023a).

The Food and Agriculture Organization of the United Nations (FAO) actively supports the efforts of Member countries to better manage human-wildlife conflicts by facilitating cross-sectoral dialogues among stakeholders for sharing information; generating guidance on good practices; providing technical guidelines for the development of national policies and legal frameworks; and implementing field activities (FAO, 2023a). Examples include:

- In response to related requests by the African Forestry and Wildlife Commission, FAO has produced a series of educational technical publications, ranging from a general overview of HWC in Africa to more specific reports on elephant, lion, baboon and crocodile conflicts (FAO, 2023a).
- FAO, in collaboration with CIRAD, BIO-HUB, WWF, and CAMPFIRE Association, developed a human-wildlife conflict toolkit in 2012. The toolkit has a range of resources designed for use by rural farmers and local communities and addresses all dimensions of HWC. It has been field-tested in FAO Technical Cooperation Programme projects in Zimbabwe and Mozambique and delivered through training workshops in the Southern, Central and Eastern Africa subregions. To raise awareness in Zimbabwe, an HWC management interpretation centre – funded by FAO and partners – was established in the Mukuvisi woodlands and officially opened in 2014 (FAO, 2023a).
- In Central Africa, a national strategy and action plan was developed in Gabon, and a subregional workshop was held to adopt the HWC toolkit produced for Southern Africa. This led to the production of a prototype for the Central African subregion in collaboration with CIRAD and the Network of Protected Areas of Central Africa (FAO, 2023a).
- In Botswana's North-West District, in 2019, FAO supported local communities to monitor areas with community scouts, fortify predator-proof traditional bomas and engage local communities in wildlife-based tourism. In Zimbabwe, FAO and partners have helped local authorities and affected communities to formulate a human-wildlife mitigation strategy, promote sustainable natural resource management for alternative livelihoods and vaccinate livestock against Foot and Mouth Disease (FAO, 2023a).
- In relation to the formulation of HWC case-specific policies and strategies, technical government officials from 11 African countries came together in 2019 for an FAO-organized multisectoral dialogue in Ghana, where policy priorities and cross-sectoral actions to address human-wildlife conflict were mapped out (FAO, 2023a).
- Currently, FAO is supporting field initiatives in several countries of the Southern African region, including Zimbabwe, Zambia and Botswana (FAO, 2023a).

Many international organisations are involved in sustainable wildlife management. The FAO Forestry Department has served as the secretariat for the Collaborative Partnership on Sustainable Wildlife Management (CPW) since 2013 and actively engaged in a wide range of the CPW's initiatives as a proactive member of the Partnership (FAO, 2023b).

Collaborative Partnership on Sustainable Wildlife Management (CPW) is a voluntary partnership of 13 international organizations with substantive mandates and programmes to promote the sustainable use and conservation of wildlife resources. The CPW,

Preliminary – Corrections Pending

established in March 2013 in Bangkok, Thailand, provides a platform for addressing wildlife management issues that require national and supra-national responses and also works to promote and increase cooperation and coordination on sustainable wildlife management issues among its members and partners (FAO, 2023b).

The mission of the CPW is to increase cooperation and coordination on sustainable wildlife management issues among its members, where such adds value, in order to promote the sustainable management of terrestrial vertebrate wildlife in all biomes and geographic areas, contributing to the conservation and sustainable use of biodiversity, and to human food security, livelihoods and well-being (FAO, 2023b). It has the following thematic objectives

- To support countries to ensure that the use and trade of wildlife is legal, sustainable and safe;
- To raise awareness of the links between sustainable use of wildlife, food security, livelihoods and well-being, culture and the integrity of landscapes;
- To promote the prevention, management and reduction of human-wildlife conflict and enhance coexistence;
- To embed the sustainable use and management of wildlife in the One Health agenda; and
- To advocate for sustainable and inclusive wildlife economies (FAO, 2023b).

WHO works together with international organizations and national institutions in charge of animal health to improve the rapid detection of emerging pathogens and to ensure coordination in rapid control measures. By strengthening the contribution of the veterinary sector in the implementation of the IHR (2005), WHO and its partners propose guidance, methods, and tools to jointly review synergies and gaps in the coordination between the two sectors and to support countries in the operationalization of a multisectoral, One Health approach for global health security (WHO, no date a).

In the context of the renewed interest from Member States to strengthen work on One Health and prevention of emerging zoonoses and the work of WHO Governing bodies on One Health, the WHO One Health Initiative team was set up to serve as the Secretariat of One Health High-Level Expert Panel (OHHLEP), WHO coordination mechanism for its One Health activities and the quadripartite collaboration (WHO, no date a).

Investing in One Health contributes to WHO's vision to promote health, keep the world safe and serve the vulnerable. WHO works to integrate the One Health approach into the global health narrative, grounded in strong political leadership, technical expertise and inclusive implementation led and owned by countries (WHO, no date a).

WHO and partner organizations are working to increase the adoption of the One Health approach in national, regional and international health policies through intersectoral political and strategic leadership; operationalizing responses and scaling up of country support, including research and policy assessment; strengthening country capacities; and monitoring of risks and preparedness for early detection and response to emerging pathogens (WHO, no date a).

Through the combined energies of the Quadripartite organizations (FAO, OIE, UNEP & WHO), a comprehensive One Health Joint Plan of Action is in development, supported and advised by the One Health High-Level Expert Panel. The Plan aims to mainstream and operationalize One Health at the global, regional and national levels; support countries in establishing and achieving national targets and priorities for interventions; mobilize investment; promote a whole-of-society approach; and enable collaboration, learning and exchange across regions, countries and sectors (WHO, no date a).

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Coordinating agency or organisation

Food and Agriculture Organization of the United Nations, World Health Organization, International Union for Conservation of Nature.

Preliminary – Corrections Pending

BI0605 / BIOLOGICAL / Human-Animal Interaction

Snakebite envenoming

Definition

A snakebite envenoming is a potentially life-threatening disease caused by toxins in the bite of a venomous snake (WHO, 2023).

Reference

WHO, 2013. Snakebite Envenoming. World Health Organization (WHO). www.who.int/health-topics/snakebite Accessed 15 February 2025.

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Annotations

Synonym

Snake bite, snakebite, snake envenoming

Additional scientific description

Snake bite is a neglected public health issue in many tropical and subtropical countries. Most of these occur in Africa, Asia and Latin America. In Asia up to 2 million people are envenomed by snakes each year, while in Africa there are an estimated 435 000 to 580 000 snake bites annually that need treatment. Envenoming affects women, children and farmers in poor rural communities in low- and middle-income countries. The highest burden occurs in countries where health systems are weakest and medical resources sparse (WHO, 2023).

Bites by venomous snakes can cause acute medical emergencies involving severe paralysis that may prevent breathing, cause bleeding disorders that can lead to fatal haemorrhage, cause irreversible kidney failure and severe local tissue destruction that can cause permanent disability and limb amputation. Children may suffer more severe effects and can experience the effects more quickly than adults due to their smaller body mass (WHO, 2023).

In contrast to many other serious health conditions, a highly effective treatment exists. Most deaths and serious consequences of snake bites are entirely preventable by making safe and effective antivenoms more widely available and accessible. High quality snake antivenoms are the most effective treatment to prevent or reverse most of the venomous effects of snake bites (WHO, 2023).

Bites by venomous snakes can cause paralysis that may prevent breathing, bleeding disorders that can lead to a fatal haemorrhage, irreversible kidney failure and tissue damage that can cause permanent disability and limb amputation (WHO, 2023).

Agricultural workers and children are the most affected. Children often suffer more severe effects than adults, due to their smaller body mass (WHO, 2023).

Metrics and numeric limits

In 2023, the World Health Organization (WHO) reported an estimated 5.4 million people worldwide are bitten by snakes each year with 1.8 to 2.7 million cases of envenoming and around 81 410 to 137 880 people dying each year because of snake bites, and around three times as many amputations and other permanent disabilities are caused by snakebites annually (WHO, 2023).

Key relevant UN convention / multilateral treaty

Not identified.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Snakebite envenoming is a potentially life-threatening disease caused by toxins in the bite of a venomous snake. Envenoming can also be caused by having venom sprayed into the eyes by certain species of snakes that have the ability to spit venom as a defence measure (WHO, no date).

Inadequate past efforts to control snakebite envenoming have produced fragmented, inaccurate epidemiological data. Many victims do not attend health centres or hospitals and instead rely on traditional treatments. However, available data show that 4.5–5.4 million people get bitten by snakes annually. Of this, 1.8–2.7 million develop clinical illness and 81 000 to 138 000 die from complications (WHO, no date).

High-risk groups include rural agricultural workers, herders, fishermen, hunters, working children, people living in poorly constructed houses and those with limited access to education and healthcare. Morbidity and mortality occur most frequently among young people and children suffer higher case fatality. Furthermore, women experience increased barriers to accessing medical care in some cultures and pregnant women are extremely vulnerable (WHO, no date).

An ongoing crisis restricting access to safe, effective antivenom treatment in many regions, particularly sub-Saharan Africa, is one factor that contributes to the predisposition to seek help through traditional medicine (WHO, no date).

Impacts: Bites by venomous snakes can cause acute medical emergencies involving severe paralysis that may prevent breathing, cause bleeding disorders that can lead to fatal haemorrhage, cause irreversible kidney failure and severe local tissue destruction that can cause permanent disability and limb amputation. Children may suffer more severe effects and can experience the effects more quickly than adults due to their smaller body mass (WHO, 2023).

Multi-hazard Context: Envenoming affects women, children and farmers in poor rural communities in low- and middle-income countries. The highest burden occurs in countries where health systems are weakest and medical resources are sparse (WHO, 2023). An increased incidence of snakebite envenoming may be associated with the following natural hazards (floods, earthquakes, volcanic activity, typhoons, hurricanes and cyclones, landslides, tsunami events), the extractive industry (mining, forestry), and land use (agricultural activity like rice, sugar cane, oil palm, copra, rubber, tea, coffee, banana plantations and other agribusiness involving manual labour).(WHO, 2023).

Monitoring: Under-reporting of snake bite incidence and mortality is common, examples include reports from Nepal, India and Sri Lanka:

- In Nepal, for example, where 90% of the population lives in rural areas, the Ministry of Health reported 480 snake bites resulting in 22 deaths for the year 2000 yet figures for the same year collected in a community-based study of one region (eastern Nepal) detailed 4078 bites and 396 deaths (Sharma et al., 2004).
- A very large community-level study of snakebite deaths in India gave a direct estimate of 45 900 (99% CI: 40 900-50 900) deaths in 2005, which is over 30 times higher than the Government of India's official figure (Mohapatra et al., 2011). Revised estimates based on verbal autopsies and other data now suggest that as many as 1.2 million Indians died from snakebite envenoming between 2000-2019 (an average of 58 000/year) (Suraweera et al., 2020).
- A comparison of hospital-registered deaths in one district of Sri Lanka to data from the Registrar-General's office on deaths demonstrated that 62.5% of deaths from snakebite envenoming were not reported in hospital data (Fox et al., 2006).

Risk Management: in contrast to many other serious health conditions, a highly effective treatment exists for envenoming. Most deaths and serious consequences of snake bites are entirely preventable by making safe and effective antivenoms more widely available and accessible. High-quality snake antivenoms are the only effective treatment to prevent or reverse most of the venomous effects of snake bites (WHO, 2019). Issues include:

- A significant challenge in manufacturing antivenoms is the preparation of the correct immunogens (snake venoms). At present very few countries have the capacity to produce snake venoms of adequate quality for antivenom manufacture, and many manufacturers rely on common commercial sources. These may not properly reflect the geographical variation that occurs in the venoms of some widespread species. In addition, lack of regulatory capacity for the control of antivenoms in countries with significant snake bite problems results in an inability to assess the quality and appropriateness of the antivenoms (WHO, 2023).
- A combination of factors has led to the present crisis. Poor data on the number and type of snake bites have led to difficulty in estimating needs, and deficient distribution policies have further contributed to manufacturers reducing or stopping production or increasing the prices of antivenoms. Weak regulation and the marketing of inappropriate or poor quality antivenoms have also resulted in a loss of confidence in some of the available antivenoms by clinicians, health managers, and patients, which has further eroded demand (WHO, 2023).
- Snake antivenom immunoglobulins (antivenoms) are the only specific treatment for envenoming by snakebites. Antivenoms can prevent or reverse most of the snakebite envenoming effects and play a crucial role in minimising mortality and morbidity. These preparations are included in the WHO List of Essential Medicines and should be part of any primary health care package where snakebites occur. Currently, there is an urgent need to ensure the availability of safe, effective and affordable antivenoms, particularly to people in developing countries, and to improve the regulatory control over the manufacture, import and sale of antivenoms (WHO, 2018).

The WHO has taken steps to raise the awareness of health authorities and policymakers on this issue. In December 2015, a

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programme to evaluate the potential safety and effectiveness of current antivenom products intended for use in sub-Saharan Africa was launched by the WHO. The results of this detailed technical and laboratory assessment will provide procurement agencies with informed guidance on which antivenoms best suit their needs. Following a request by several United Nations member states, the WHO formally listed snakebite envenoming as the highest priority neglected tropical disease in June 2017 (WHO, 2023).

Regional engagement by the WHO has taken place and various resources are now available.

- The guidelines for the Prevention and Clinical Management of Snakebite in Africa were developed by the WHO Regional Office of Africa with contributions from technical experts. They are meant to assist health workers to improve medical care for snakebite victims. The guidelines discuss snakes, snake venoms and snakebites and their consequences with emphasis on the medically important snakes, namely those causing serious envenoming. The volume contains over a hundred snake photographs, clinical signs of envenoming and the consequences. The guidelines also feature various annexes and in particular the geographical distribution of African venomous snakes, as well as their classification, habitats and clinical toxinology (WHO, 2010).
- The incidence of snakebite mortality is particularly high in South-East Asia. Rational use of snake anti-venom can substantially reduce mortality and morbidity due to snakebites. These guidelines are a revised and updated version of the Regional Guidelines for the Management of Snakebites published by the WHO Regional Office in South-East Asia in 2011 and updated in 2016. These guidelines aim to promote the rational management of snakebite cases in various health facilities where trained health functionaries and quality snake antivenom are available (WHO, 2013).

A Snakebite Envenoming Working Group established that same year was tasked with informing the development of a strategic WHO road map on snakebites. This strategy focuses on a 50% reduction in mortality and disability caused by snakebite envenoming by 2030. This aim will be achieved through four key objectives: empower and engage communities; ensure safe, effective treatment; strengthen health systems; and increase partnerships, coordination and resources (WHO, 2023).

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Coordinating agency or organisation

World Health Organization.

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TECHNOLOGICAL

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TL0101 / TECHNOLOGICAL / Cyber Hazards

Malware

Definition

Malware is a summary term for different forms of malevolent software designed to infiltrate and infect computers, typically without the knowledge of the owner (ITU, 2008).

Reference

ITU, 2008. ITU Study on the Financial Aspects of Network Security: Malware and Spam. International Telecommunication Union (ITU). www.itu.int/ITU-D/cyb/cybersecurity/docs/itu-study-financial-aspects-of-malware-and-spam.pdf Accessed 31 October 2024.

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Annotations

Synonyms

Malicious software, Viruses, Worms, Trojan horses, Rogue software, Malicious code, Ransomware, Spyware, Botnet, Wiper attack, Rootkit, Keylogger, Adware, Crypto-jacking, Malvertising, logic bombs, Polymorphic malware/ mutating malware, MALSPAM.

Additional scientific description

Malware is a portmanteau of "malicious software". It refers to software designed to cause damage, disrupt operations, or gain unauthorized access to computer systems, networks, or devices. It encompasses various harmful software types, each with specific characteristics and propagation methods. Malware is often categorized into “families” (referring to a particular type of malware with unique characteristics) and “variants” (usually a different version of code in a particular family) (International Telecommunication Union, 2008).

Malware encompasses various types of software, such as:

- Viruses: attach themselves to legitimate programs and propagate from device to device when those programs are executed.
- Worms: replicate themselves to spread to other systems without needing a host program.
- Trojan horses: masquerade as benign software to trick users into executing them, thereby compromising the system.
- Ransomware: cyber criminals encrypt data and demand payment in return for decryption keys.
- Spyware: covertly gathers information by monitoring users’ activities.
- Wiper: permanently deletes or corrupts data stored on infected machines.
- Rootkits: enables unauthorized access by hiding their presence within the system.

The history of malware dates back at least to the 80s, when the first ones were created (Milošević, 2014). Notable incidents include the Morris Worm in 1988, which disrupted a significant portion of the early internet, and the more recent WannaCry ransomware attack in 2017, which affected organizations worldwide.

Malware can be delivered through multiple vectors, such as email attachments (especially in the context of phishing attacks), malicious websites, infected software downloads, or via network vulnerabilities. Today, attackers can leverage artificial intelligence to create advanced malware, such as polymorphic ones, which can alter their code to evade detection by traditional security measures.

In addition, fileless malware is an increasing threat due to its ability to evade detection by traditional antivirus programs (Liu et al., 2024). Unlike standard malware that depends on files or executables, fileless malware exploits legitimate system tools and leverages existing files, applications and system services to implement malicious activities. Fileless malware can enter systems through multiple vectors, such as phishing emails, compromised websites, or watering hole attacks. Once it gains access, it can steal sensitive information and spread the infection throughout the network.

Malwares can become national and international hazards when other systems are targeted deliberately or otherwise e.g. third-party suppliers being targeted, or one of their suppliers or sub-suppliers. A precedent is the Stuxnet worm discovered in 2010, which was designed to sabotage Iran's nuclear facilities. This sophisticated malware highlighted the potential for cyber weapons to cause physical damage and disrupt national security (Zetter, 2014).

Malicious actors frequently rely on malware due to its versatility and effectiveness. Malware remains one of the most common forms of cyber-attack, with millions of new malware samples detected annually (Statista, 2024). It serves various purposes, from financial gain through ransomware to espionage and disruption of services.

Metrics and numeric limits

Over 1 billion new malware variants were detected globally in 2023 (Statista, 2024).

Key relevant UN convention / multilateral treaty

International legal instruments addressing malware are encompassed within broader cybercrime frameworks.

The Council of Europe's Budapest Convention on Cybercrime provides guidelines for international cooperation in combating cybercrime, including offences involving the creation, distribution, or use of malware.

The Pall Mall Process Code of Practice for States updated 2025 is a globally inclusive dialogue to address the proliferation and irresponsible use of commercial cyber intrusion tools and services.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Software vulnerabilities, Rise in digital dependency, Cybercrime economy, Geopolitical tensions.

Impacts: Malware attacks can escalate to national hazards when they target critical infrastructure or government systems. A precedent is the Stuxnet worm discovered in 2010, which was designed to sabotage Iran's nuclear facilities. This sophisticated malware highlighted the potential for cyber weapons to cause physical damage and disrupt national security[1].

Malware can result in significant disruption to services, financial loss, potential revenue loss, data and intelligence loss or theft, loss or damage to IT infrastructure, reputational damage to organisations and individuals, and result in significant payment of ransoms and regulatory fines. There may also be increased costs in recovery. In addition, the impacts of a successful malware attack can contribute to the loss of public trust in organisations, politicians, and the public sector. There is also the threat of further exploitation if information is compromised.

Software systems are interconnected with physical systems. Malware can be used to enable access to systems that can open up other hazards such as increasing chemicals in water distribution facilities to poison large parts of the population by tampering with water systems. This has been attempted in Florida (2021), California (2021), Israel (2020), and USA (2016) (Sikder et al., 2023).

Multi-hazard Context: Not Applicable.

Monitoring: Threat monitoring is undertaken at international, national, sectoral and organisational levels where information on malware identification is shared via various mechanisms to mitigate the risks.

Risk Management: Defending against malware requires, first, user awareness since most of the malware is activated following a user-generated input (like clicking on fraudulent or compromised links). Technical measures, including the use of antivirus and anti-malware software, regular system updates and patches, and network segmentation, can provide additional layers of protection but should not be considered as an alternative to user awareness.

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Coordinating agency or organisation

International Telecommunication Union (ITU).

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TL0102 / TECHNOLOGICAL / Cyber Hazards

Data Breach & PII Breach

Definition

A data breach occurs when the data for which a company/organisation is responsible suffers a security incident resulting in a breach of confidentiality, availability or integrity (European Commission, no date).

Reference

European Commission, no date. What is a data breach and what do we have to do in case of a data breach? https://commission.europa.eu/law/law-topic/data-protection/reform/rules-business-and-organisations/obligations/what-data-breach-and-what-do-we-have-do-case-data-breach_en. Accessed 31 October 2024.

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Annotations

Synonyms

Data spill, Data leak, Security breach, Intellectual data breach, personally identifiable information (PII) breach, information breach, data compromise, data exposure

Additional scientific description

A data breach in cybersecurity refers to an incident where sensitive, protected, or confidential data is accessed, disclosed, or retrieved without authorization. This can involve personal data, financial information, intellectual property, or other critical data, leading to potential harm to individuals or organizations.

Data breaches manifest in various forms, such as unauthorized access to databases, interception of data in transit, or insider threats. Personal data breaches compromise personally identifiable information (PII), such as names, addresses, social security numbers, and financial details, leading to identity theft and privacy violations. Non-personal data breaches pertain to the exposure of proprietary business information, intellectual property, or other sensitive organizational data, potentially causing financial losses and competitive disadvantages.

Data breaches can escalate to national hazards when they target critical infrastructure, government agencies, or large-scale data repositories. A precedent is the 2015 data breach of the U.S. Office of Personnel Management, where sensitive information of over 21 million federal employees was compromised, posing significant risks to national security and intelligence operations (Koerner, 2016). In 2022, 1,774 data breaches affected more than 392 million individuals worldwide, exposing legally protected information that identified people accessing services across sectors like finance, healthcare, and social services. These data breaches also have a significant economic impact, with their costs increasing by over 20% annually, now accounting for 4-6% of the global GDP (WEF, 2023).

The human factor is the most prevalent vulnerability, accounting for 68% of breaches linked to unintentional human actions. Social engineering tactics often deceive individuals into clicking malicious links or sharing sensitive information, which can then be exploited (Verizon, 2024).

Metrics and numeric limits

Not available.

Key relevant UN convention / multilateral treaty

International legal instruments addressing data breaches include the Council of Europe's Convention on Cybercrime (Budapest Convention), which facilitates international cooperation in combating cybercrime, including unauthorized access and data interference.

Additionally, numerous national and regional regulations deal with personal data breaches, like the European Union's General Data Protection Regulation, the California Consumer Privacy Act, the Canadian Personal Information Protection and Electronic Documents Act, etc.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Lack of cybersecurity investment, Human error, Third-party risk, Increasing attack surface via APIs. Future breaches are likely to focus on major tech companies that handle large customer bases and significant amounts of sensitive data. This increased targeting stems from factors such as the widespread use of APIs, the growth of data digitization, and undetected zero-day vulnerabilities.

Impacts: In 2023, the landscape of global data breaches significantly intensified from previous years, including a 72% increase in the number of data compromises over the previous high in 2022 (WEF, 2024).

Despite the rise in breaches, breach notifications are becoming more unclear. In 2022, 66% of public notices in the United States did not provide information on the affected victims or the specifics of the attack, mainly due to the lack of national privacy laws. Additionally, post-breach services, such as credit monitoring, often fail to align with the recommended steps to reduce the risk of future exposures and breaches (WEF, 2023).

The consequences of data breaches can be severe, leading to financial losses, reputational damage, legal and regulatory implications, operational disruption, and harm to individuals (identity theft, privacy violations etc) or organisations. Data breaches can expose organisations and individuals to further hazards such as increased cybersecurity threats e.g. malware, data manipulation (disrupting operations/triggering misinformation etc.), and supply chain disruption (to third-party vendors and partners resulting from a cascade of security issues across interconnected systems).

Multi-hazard Context: Not Applicable

Monitoring: Not Applicable

Risk Management: To effectively address and mitigate these risks, organizations should take proactive steps to protect consumer information and define clear, actionable key performance indicators. Companies should be encouraged to implement customer multi-factor authentication services and collaborate to establish industry standards. Insurers and regulators can promote awareness and reduction of data breaches by offering incentives to organizations that prioritize consumer data protection and enterprise security. Cyber insurance can support this approach by providing lower premiums, free pre-breach services, and ongoing underwriting that adapts to changing threats and evolving cyber risk management practices.

The most appropriate strategy to mitigate the risk of a data breach depends on how the attack is carried out.

- Credential Theft Attacks: Implementing strong password policies and multi-factor authentication (MFA), alongside using password managers and regularly updating credentials (Kost, 2024).
- Phishing Attacks: Conducting regular employee training and awareness programs and Implementing email security measures like anti-spoofing and encryption.
- Vulnerability Exploitation: Maintaining a robust patch management system, conducting regular vulnerability assessments and penetration testing, and Implementing network segmentation to isolate critical systems.

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Coordinating agency or organisation

International Telecommunication Union (ITU).

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TL0103 / TECHNOLOGICAL / Cyber Hazards

Advanced Persistent Threat

Definition

An advanced threat is created by an adversary with sophisticated levels of expertise and significant resources, allowing it, through the use of multiple different attack vectors (e.g., cyber, physical, and deception), to generate opportunities to achieve its objectives (NIST, 2012).

Reference

National Institute for Standards and technology, 2012. Guide for conducting risk assessments. https://doi.org/10.6028/NIST.SP.800-30r1 Accessed 25 January 2025.

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Annotations

Synonyms

Sponsored cyber-attack, State operation, Cyber espionage, Stealth cyber-attack.

Additional scientific description

An Advanced Persistent Threat (APT) in cybersecurity refers to a prolonged and targeted cyber-attack where, often, an unauthorized user gains access to a network and remains undetected for an extended period. The primary goal of APTs is typically to observe network activity, steal data, or cause disruptions, rather than inflicting immediate damage. This threat is considered to be "advanced" due to the sophisticated techniques employed to exploit vulnerabilities, and "persistent" because of the continuous effort to achieve a specific objective.

One of the earliest recognized APT incidents was the Titan Rain attacks between 2003 and 2006, where attackers infiltrated U.S. defence networks to steal sensitive information (Council of Foreign Relations 2005). The discovery of the Stuxnet worm in 2010 marked a significant escalation, demonstrating APTs' capacity to cause physical damage by targeting Iran's nuclear centrifuges (Zetter 2014). Another notable example is the Operation Aurora attack in 2009, which targeted multiple companies, including Google, to access intellectual property and activists' email accounts (Council of Foreign Relations 2010). Recent incidents, such as SolarWinds (2020) and Nobelium's campaigns (2022), exemplify evolving APT techniques targeting supply chains and cloud infrastructure (Ghanbari et al., 2024).

APTs employ a multifaceted array of techniques to achieve their objectives. These attacks are designed around the characteristics of their targets and therefore can take many forms. Often, these begin with an intrusion into the target of the system using spear-phishing, zero-day vulnerabilities (unknown security flaws) or other advanced techniques to infiltrate systems undetected. Once inside, attackers can either stay silent, monitoring traffic and gathering information, or they can use lateral movement to navigate the network, employing privilege escalation to access sensitive areas. Persistence is maintained through deploying backdoors and rootkits, enabling ongoing access and data exfiltration without triggering security alarms.

Malicious actors, particularly nation-state groups and organized cybercriminals, frequently rely on APTs due to their effectiveness in achieving long-term strategic goals. While less common than mass-targeted attacks like ransomware, APTs represent a significant proportion of high-impact cyber incidents. Their complexity and potential for substantial damage make them preferred methods for espionage, intellectual property theft, or sabotage.

Metrics and numeric limits

Not applicable.

Key relevant UN convention / multilateral treaty

International legal instruments addressing APTs are encompassed within broader cybersecurity and cybercrime frameworks. The Council of Europe's Budapest Convention on Cybercrime provides a basis for international cooperation in combating cyber offences, including those involving APTs.

United Nations resolutions on cybersecurity encourage member states to adopt measures to protect critical infrastructure and promote information exchange to prevent cyber threats. However, the absence of specific treaties focused solely on APTs highlights challenges in addressing such sophisticated and evolving threats globally.

Since APTs are often carried out by State actors, their regulation would fall under the scope of International Public Law.

Examples of hazard drivers, impacts, and risk management

Hazard drivers: Not Applicable

Impacts: Not Applicable

Multi-hazard Context: Not Applicable

Monitoring: Not Applicable

Risk Management: Defending against an APT is a complex task, considering the amount of time, resources, and effort the attacker is willing to expend to fulfil its operation.

Moreover, given the diverse approach APT can adopt, it is difficult to prescribe a priori strategies to minimize the risk, applicable to all cases. The complex and evolving nature of APTs requires a tailored and adaptive defence approach, as no single solution can address all potential threats. Instead, organizations must integrate multiple strategies to ensure robust protection.

According to Asharani et al. (2019), defence strategies against Advanced Persistent Threats (APTs) are categorized into three main groups: monitoring, detection, and mitigation. Each plays a critical role in minimizing the risk of unauthorized access.

- Monitoring Methodologies: These involve using tools like firewalls and antivirus software to observe various parts of the system. Advanced firewalls are capable of analysing traffic for known malicious patterns and signatures, as well as employing behavioural analysis to detect abnormal activity. Additionally, monitoring CPU usage is important, as unusual patterns in resource utilization can indicate suspicious behaviour.
- Detection Methodologies: These include employing various anomaly detection methods, such as static analysis, neural networks, and machine learning approaches (Hodge and Austin et al., 2004). These techniques help identify APTs that persist over the medium to long term. For instance, an Intrusion Detection System (IDS) can analyse network traffic to spot unusual activity and alert security teams to potential threats.

Mitigation Methodology: APT mitigation can be achieved through reactive and proactive approaches. Reactive methods involve identifying potential attack paths and vulnerabilities at a given moment, predicting critical areas, and assessing their severity. Proactive strategies, on the other hand, focus on deceiving attackers. These techniques aim to mislead intruders and cause them to alter their attack strategies, thereby reducing the threat's impact.

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Coordinating agency or organisation

Not identified

Preliminary – Corrections Pending

TL0104 / TECHNOLOGICAL / Cyber Hazards

Denial of Service

Definition

Denial of service is the prevention of authorised access to resources or the delaying of time-critical operations. (Time-critical may be milliseconds or it may be hours, depending upon the service provided) (NIST, 2017).

Reference

NIST, 2017. Computer Security. An Introduction to Information Security. Special Publication 800-12 Revision. National Institute of Standards and Technology (NIST). https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-12r1.pdf Accessed 25 January 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Outage, Loss/degradation of availability, DoS, Distributed Denial of Service (DDoS), Service Disruption Attack, Flood Attack, Botnet Attack.

Additional scientific description

A Denial of Service (DoS) renders a computer system or network unavailable to its intended users by overwhelming it with external inputs (e.g., incoming web traffic), in which cases it takes the name of Distributed Denial of Service (DDoS) or exploiting its vulnerabilities to exhaust the computational resources. This disruption denies users access to services and information, causing significant operational and financial impacts (CISA, 2021).

Distributed denial of service (DDoS) attacks remain a persistent nuisance on the Internet. They exploit the fact that the Internet lacks centralized access control. Since this vulnerability was a core design decision of the early Internet, DDoS attacks have persisted. Early attacks were related to hacker culture, but their focus quickly changed to commercial exploitation. There have also been a number of political uses of DDoS, including cyberwar, hacktivism, and terrorism (Brooks et al, 2021).

The use of DoS and DDoS is well documented in cybersecurity history. Early attacks can be found already in the early internet era, with one of the first incidents occurring in France in 1995, followed the next year by a major incident against Panix, a New York City-based internet service provider (Brooks et al, 2021). Over the years, these attacks have evolved in complexity and scale, exemplified by the 2016 botnet attack powered by Mirai malware, which leveraged Internet of Things (IoT) devices to launch a massive DDoS attack, disrupting major websites worldwide (CISA, 2017).

DoS can result from human errors (such as misconfiguration), other incidents (such as power failure), or deliberate attacks. Various techniques are employed in DoS attacks. The primary distinction lies between DoS and DDoS attacks. A DoS attack usually originates from a single source targeting a system, while a DDoS attack involves multiple compromised systems, often forming a botnet, to flood the target simultaneously, making defence significantly more challenging. The increasing number of connected devices – especially in the context of the Internet of Things (IoT) boom – is also increasing the risk of DDoS attacks occurring since each connected device can potentially become part of a botnet.

A denial-of-service (DoS) attack occurs when legitimate users are unable to access information systems, devices, or other network resources due to the actions of a malicious cyber threat actor. A denial-of-service condition floods the targeted host or network with traffic until the target cannot respond or simply crashes, affecting email, websites, online accounts (e.g., banking), or other services. DoS attacks can cost an organization both time and money while their resources and services are inaccessible.

DoS attacks can be further categorized based on method: volume-based attacks overwhelm the bandwidth of a network (e.g., flooding a website with excessive traffic), whereas attacks exploiting computational limitations involve sending malformed requests or initiating infinite loops to exhaust computational resources.

DoS attacks can escalate to national hazards when they target critical infrastructure. A precedent is the 2007 cyber-attacks on Estonia, where coordinated DDoS attacks crippled government, banking, and media websites, leading to widespread disruption and highlighting vulnerabilities at the national level (Ottis, 2008).

DoS attacks are commonly employed by malicious actors due to their relative ease of execution and potential for significant disruption. Every year, data registers large numbers of DoS and DDoS incidents, making them one of the most prevalent forms of cyber-attack (Bergamini de Neira et al, 2023). In 2024, NETSCOUT reported over 13 million DDoS attacks globally, with rising trends in multi-vector attacks (NETSCOUT, 2024).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: One of the most critical factors leading to the increase in DDoS is the proliferation of unsecured IoT devices. The extensive connectivity and insufficient security protocols in modern networks provide fertile ground for attackers to exploit vulnerabilities and launch successful DoS attacks.

Impacts: A denial-of-service (DoS) attack occurs when legitimate users are unable to access information systems, devices, or other network resources due to the actions of a malicious cyber threat actor. Services affected may include email, websites, online accounts (e.g., banking), or other services that rely on the affected computer or network. (CISA, 2021). DDoS attacks can exacerbate healthcare or financial system failures during natural disasters or pandemics." (ENISA, 2023).

Multi-hazard Context: Not Available

Monitoring: Not Available

Risk Management: Minimizing the risk of DoS involves a combination of technological and strategic measures. Implementing robust network security protocols, utilizing intrusion detection and prevention systems, and adopting AI-driven security solutions enhances an organization's resilience. Additionally, strategies, like rate limiting, traffic filtering, and employing content delivery networks, help mitigate the impact of attacks.

Artificial intelligence can also play a critical role in protecting against DoS. Artificial intelligence systems can analyse network traffic to identify anomalies, enabling real-time detection and response, enhance the capability to filter malicious traffic, allocate resources dynamically, and predict potential threats based on patterns and behaviours.

The ITU improves cybersecurity readiness, protection, and incident response capabilities of Member States by conducting CyberDrills at the regional and international level (ITU, no date). A CyberDrill is an annual event during which cyber-attacks, information security incidents, or other types of disruption are simulated to test an organization's cyber capabilities, from being able to detect a security incident to the ability to respond appropriately and minimize any related impact. Through CyberDrills, participants can validate policies, plans, procedures, processes, and capabilities that enable the preparation, prevention, response, recovery, and continuity of operations.

Preliminary – Corrections Pending

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Coordinating agency or organisation

International Telecommunication Union (ITU).

Preliminary – Corrections Pending

TL0105 / TECHNOLOGICAL / Cyber Hazards

Supply Chain Attack

Definition

A supply chain attack is when products, services, or technology you are supplied with have been breached or compromised, and are in turn used to infiltrate and further compromise your own systems (ICO, no date).

Reference

ICO, no date, Supply Chain Attack. https://ico.org.uk/about-the-ico/research-reports-impact-and-evaluation/research-and-reports/learning-from-the-mistakes-of-others-a-retrospective-review/supply-chain-attacks/ Accessed 25 January 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Third-party compromise, Software supply chain breach, Dependency-based attack.

Additional scientific description

In cybersecurity, supply chain attacks refer to exploiting security weaknesses within an organization's supply chain to infiltrate its systems and networks. Attackers target less secure elements of the supply chain – such as third-party vendors, suppliers, or service providers such as cloud providers – with the aim of compromising the end target by leveraging the interconnectedness of modern digital ecosystems. This method allows attackers to bypass traditional security measures by exploiting trusted relationships.

The history of supply chain attacks has evolved alongside the increasing complexity of global supply networks. Notable early instances include the 2011 attack on RSA Security, where attackers compromised SecurID tokens through a supplier to breach defence contractors (Greenberg, 2021). More recently, the 2020 SolarWinds attack demonstrated the severe impact of such breaches. In this incident, sophisticated threat actors inserted malicious code into the company's software updates, affecting numerous government and private organizations worldwide and highlighting the vulnerabilities inherent in supply chains (Williams, 2020).

Various techniques are employed in supply chain attacks. These include tampering with software updates (such as in the SolarWinds attack), compromising code repositories, infecting hardware components during manufacturing, and exploiting vulnerabilities in third-party services. Attackers may insert malicious code into legitimate software updates or leverage backdoors in hardware devices to gain unauthorized access.

Many organizations depend on third-party service providers to manage their cloud environments, which has led attackers to focus on these providers in a unique form of supply chain attack–identity-based attacks. These attacks exploit the extensive permissions often granted to service provider accounts, which may have access to multiple customer environments. This interconnected access increases the potential impact of a compromise, making service providers an attractive target (Microsoft, 2023).

One of the most significant supply chain attacks stems from open-source software. Open-source communities offer numerous modules and packages widely used by businesses globally, including those in supply chains. However, because open-source software often lacks clear ownership and guaranteed security, it frequently introduces vulnerabilities into security architectures. (Forbes, 2022) Another prominent technique in supply chain attacks includes hijacking updates and compromising code signing. Software vendors routinely distribute updates from

centralized servers to maintain and enhance their products. Threat actors can exploit this process by infiltrating the vendor's network to insert malware into an update or modify it to gain unauthorized control over the software's functionality. Code signing, a mechanism used to verify the authenticity and integrity of software, is another critical target. Malicious actors undermine this process by using self-signed certificates, exploiting misconfigured access controls, or compromising signing systems. By impersonating trusted vendors and embedding malicious code into updates, attackers can successfully execute highly deceptive and damaging attacks (NIST, 2021). In 2023, attackers compromised 3CX's desktop app through infected installers, spreading malware through a widely used VoIP system (Fortiguard, 2023).

Malicious actors increasingly rely on supply chain attacks due to their high impact and the difficulty of detection. The complexity of modern supply chains and reliance on third-party providers create numerous opportunities for exploitation, making supply chain attacks a significant concern in cybersecurity. At the same time, supply chain attacks are often targeted. Therefore, only actors with higher resources and capabilities can (usually) run them.

Metrics and numeric limits

Not applicable.

Key relevant UN convention / multilateral treaty

International legal instruments addressing supply chain attacks are encompassed within broader cybersecurity and cybercrime frameworks. The Council of Europe's Budapest Convention on Cybercrime provides guidelines for international cooperation in combating cybercrime, including offences that may involve supply chain attacks.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: These attacks, which involve exploiting or altering third-party software, hardware, or applications, pose a significant challenge for organizations.

Impacts: Fraud, theft

Multi-hazard Context: Not Applicable

Monitoring: Not Applicable

Risk Management: Defending against supply chain attacks requires a comprehensive approach that includes rigorous vetting of suppliers, implementing strict security standards, continuous monitoring, and fostering collaboration between organizations and their partners. Since many attacks rely on external vendors with complex dependencies in their tools and services, achieving complete protection can be difficult. However, organizations can adopt proactive strategies to defend against common attack vectors (Cloudflare, no date).

- Running a Third-Party Risk Assessment: This involves testing third-party software before deployment, requiring vendors to comply with specific security policies, implementing a Content Security Policy (CSP) to control executable resources in the browser, and using Subresource Integrity (SRI) to detect suspicious JavaScript content.
- Implementing Zero Trust: Zero Trust ensures that all users—employees, contractors, and vendors—are continuously verified and monitored within the organization's network. By verifying the identity and privileges of users and devices, Zero Trust prevents attackers from exploiting stolen legitimate user credentials to infiltrate the organization.
- DevSecOps: Supply chain security leverages DevSecOps to defend against attacks by first discovering all components, gaining visibility into the supply chain, and securing cloud-native application components. By integrating security throughout the development process, DevSecOps ensures real-time deployment of security operations while aligning seamlessly with business objectives (GitLab, No date).

Preliminary – Corrections Pending

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Coordinating agency or organisation

International Telecommunication Union (ITU).

Preliminary – Corrections Pending

TL0106 / TECHNOLOGICAL / Cyber Hazards

Cyberbullying

Definition

Cyberbullying is bullying that takes place using digital devices such as cell/mobile phones, computers, and tablets. Cyberbullying can occur through SMS, e-mail, apps, social media, forums, or gaming when people view, participate in, or share content. Cyberbullying includes the deliberate sending, posting, or sharing of negative, harmful, false, or mean content about someone else. It can include sharing personal or private information about someone else causing embarrassment or humiliation. Some cyberbullying may also be unlawful or criminal behaviour (adapted from UNICEF, no date; PHE, 2014; US Government, no date).

Preliminary - Corrections Pending

References

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Annotations

Synonyms

Cyber harassment, Harassment online, Online bullying, Online harassment. Digital bullying. Online abuse, Internet harassment.

Additional scientific description

The United Nations Children's Fund (UNICEF) describes cyberbullying as bullying with the use of digital technologies. It is repeated behaviour, aimed at scaring, angering or shaming those who are targeted. Examples include: spreading lies about or posting embarrassing photos of someone on social media; sending hurtful messages or threats via messaging platforms; and impersonating someone and sending mean messages to others on their behalf (UNICEF, no date).

The International Telecommunication Union (ITU) and UNICEF define cyberbullying as wilful and repeated harm inflicted

through the use of computers, cell phones, and other electronic devices (ITU & UNICEF, 2015). It may involve direct (such as chat or text messaging), semi-public (such as posting a harassing message on an e-mail list) or public communications (such as creating a website devoted to making fun of the victim).

Face-to-face bullying and cyberbullying can often happen alongside each other. But cyberbullying leaves a digital footprint – a record that can prove useful and provide evidence to help stop the abuse (UNICEF, no date). Online harassment is harassment taking place via the internet (on a social network, a forum, a multiplayer video game, or blogs).

Other cyberbullying activities include: the dissemination of photos or videos ridiculing the person; grooming; radicalisation; non-consensual diffusion of intimate photos or personal information; dissemination of false rumours; identity theft from social media accounts; impersonating another person online; sharing private messages; creating hate websites/social media pages; excluding people from online groups; flaming, or using purposeful extreme or offensive language in order to get into online arguments and fights; and cyberstalking (PHE, 2014; Broadband Commission for Sustainable Development, 2019; Family Lives, no date).

Socio-economic or educational disadvantage, disability, minority ethnic origin (some groups) and LGBT status are also indicators of a high risk for cyberbullying.

Metrics and numeric limits

UNESCO reports that Cyberbullying is a widespread issue affecting children worldwide, with half of children in Europe, 60% in the USA, and a third in South Africa reporting experiences. In the USA, it's the top classroom concern for teachers (UNESCO, 2021).

Key relevant UN convention / multilateral treaty

The United Nations Convention on the Rights of the Child (1990) calls for the protection of children's rights and safeguards them from all forms of violence, including cyberbullying. This convention outlines the essential rights necessary for the dignity and harmonious development of children (UN, 1990).

The Convention on Countering Cybercrime, approved by a UN General Assembly committee in August 2024, provides a framework for international cooperation to address various cybercrimes, including cyberbullying. It also tackles issues such as online child sexual abuse and grooming. (UN, 2024)

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: the drivers include widespread digital access, unregulated platform use, anonymity online, and algorithmic amplification of harmful content.

Impacts: Cyberbullying is a widespread issue affecting children worldwide, with half of children in Europe, 60% in the USA, and a third in South Africa reporting experiences. In the USA, it's the top classroom concern for teachers. While 84% of parents worldwide worry about online safety, 58% spend less than 30 minutes discussing it with their children. Additionally, 49% of U.S. children say their parents don't monitor their online activity, and half admit to hiding it (UNESCO, 2021).

Research has demonstrated the causal relationship between experiencing bullying and poorer health and wellbeing outcomes in children and adolescents, with potentially long-term impacts into adulthood. The negative effect of bullying has also been demonstrated among the perpetrators of bullying and not just the victims. A survey revealed that Instagram was the leading platform for cyberbullying incidents. The findings showed that 42% of young people experienced cyberbullying on Instagram, followed by 37% on Facebook and 31% on Snapchat (Ray et al., 2024).

Multi-hazard Context: There is often an interaction between being bullied and bullying others; those who are both bullies and victims (bully/victims) are likely to display the worst health and social outcomes. In summary: 20% of children and young people indicate that a fear of cyber-bullies made them reluctant to go to school; 5% reported self-harm; 3% reported an attempt of suicide as a direct result of cyberbullying (UKCCIS, 2012); As an example of impacts on mental health, Maurya et al. (2022) reported on a 3-year cohort study in India reported that adolescents experiencing cyberbullying victimisation were twice more likely to suffer from depressive symptoms than their counterparts. The internet creates not only a threat for teens who could fall victim to cyberbullying – but also the potential for children to engage in online crimes, trolling, and cyberbullying themselves (Comparitech, 2024). Radicalisation and grooming are also of concern.

Preliminary – Corrections Pending

Monitoring: Monitoring is complex and requires engagement from many partners. Helfrich et al (2020), in their review, reinforced the importance of parent involvement in cyberbullying prevention efforts and informed future prevention and intervention program development.

Risk Management: With many children vulnerable to cyberbullying and online risks, protecting them from internet-related dangers is essential. Governments, policymakers, and digital service providers should consider implementing measures to prevent abuse within the online community (Nazir & Thabassum, 2021). Schools can play a critical role by utilizing cyberbullying assessments to identify victims and perpetrators and equipping educators with proper guidelines to address such incidents. Parents should also adopt an active role in supervising younger children's internet use (Kavuk-Kalender & Kaaser, 2018). At-risk children should have easy access to helplines, hotlines, or awareness centres, along with legal support to tackle cyberbullying. To mitigate the significant privacy risks associated with children's personal information, robust measures must be enacted to protect their data (OECD, 2021).

Since cyberbullying often occurs more covertly than traditional bullying, making it harder to detect, societal awareness and education are crucial in addressing gaps where laws and regulations may fall short. Preventive actions, such as empathy training, teacher and staff development, awareness campaigns, and technology-based solutions, can further contribute to reducing cyberbullying (Özgür, 2020).

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Preliminary – Corrections Pending

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United Nations Educational, Scientific and Cultural Organization (UNESCO), 2021. Tackling cyberbullying and other forms of online violence involving children and young people: Fact sheet. https://unesdoc.unesco.org/ark:/48223/pf0000379486 Accessed 18 May 2025.

Coordinating agency or organisation

International Telecommunications Union (ITU)

Preliminary – Corrections Pending

TL0107 / TECHNOLOGICAL / Cyber Hazards

Social Engineering - Phishing

Definition

Social engineering corresponds to all techniques aimed at persuading a target into revealing specific information or performing a specific action for illegitimate reasons (ECS, no date).

Reference

ECS, no date. Social Engineering; July Awareness Calendar. European Cybersecurity Organisation (ECS) https://ecs-org.eu/ecso-uploads/2022/10/62cd2f660f602.pdf Accessed 3 April 2025

Preliminary – Corrections Pending

Annotations

Synonyms

Phishing, Psychological manipulation attack, Human hacking.

Additional scientific description

Social engineering is a manipulation technique that leverages human psychology to obtain unauthorized access to information or systems. It concentrates on the human element, frequently the weakest link in cybersecurity, rather than technical vulnerabilities. Social engineering encompasses a broad range of activities intended to exploit human error or human behaviour with the objective of gaining access to information or services. It uses various forms of manipulation to trick victims into making mistakes or handing over sensitive or secret information.

As a term, social engineering has a history that predates cybersecurity and ICT. Historically, it was associated with the control of societies and the governance techniques used by authorities to shape them. With the advent of digital technologies, the term started to shift, and by the end of 1990, it was part of the common vocabulary of hackers, solidifying its use in the cybersecurity domain (Hatfield 2018).

Digital deception has advanced significantly, contributing to the new frontier of social engineering attacks. These attacks pose serious threats to digital assets, often resulting in financial losses and privacy violations. They can be executed through various channels, including email, phishing websites, text messages, voice or video calls, and social media platforms (WEF, 2024).

The techniques used in social engineering are diverse and continually adapting. Social engineering can be looked at from at least two different perspectives: the victims they target or the approach they adopt. In the first case, a common social engineering technique is Phishing. Phishing involves sending fraudulent communications that appear to come from reputable sources, aiming to steal sensitive data like login credentials or financial information. Usually, phishing targets a wide audience, leveraging the number of attempts (e.g., spam campaigns to hundreds or thousands of people) rather than the quality (phishing attacks are usually unrefined and can be easily spotted). Spear phishing, on the other hand, is a more targeted form of phishing, focusing on specific individuals or organizations. In this case, the message sent to the victim or victims is tailored. This requires preparation and background checks of the victims, making it difficult to scale up in number but more effective towards targeted individuals. Whaling is a specific type of spear phishing that targets high-profile individuals such as executives and top managers.

From the approach perspective, social engineering can take many forms. Email messaging or other forms of online messaging (e.g., direct messages on social media) are the most common forms. Vishing (voice phishing) and smishing (SMS phishing) utilize phone calls and text messages, respectively, to deceive victims. Watering hole attacks compromise websites frequently visited by the target group, leading to malware infection. Homograph attacks exploit

similarities in character sets (e.g., replacing 'o' with '0' in URLs) to trick users, and typosquatting relies on common misspellings of legitimate websites to lure unsuspecting users (e.g., registering a website such as www.indrr.org to capture traffic from users attempting to access www.undrr.org but mistyping).

Artificial intelligence plays a significant role in enhancing social engineering attacks, including through deepfakes. AI can analyse vast amounts of data to craft highly personalized and convincing messages (for spear phishing attacks) but can also automate the delivery and management of large-scale phishing campaigns. The combination of these two characteristics is worrisome, as it might lead to a new approach capable of delivering large-scale spear-phishing campaigns (Hazell, 2023).

Social engineering is highly used by malicious actors due to its effectiveness and low cost. It is a common cyber-attack method, often serving as the initial vector for more complex intrusions (for instance, convincing a user to click on a link or download a file containing malware).

Metrics and numeric limits

Not applicable.

Key relevant UN convention / multilateral treaty

Currently, there is no specific international legal instrument that deals exclusively with social engineering. However, broader frameworks like the Budapest Convention on Cybercrime provide guidelines for combating cybercrime activities, including those facilitated by social engineering techniques (Council of Europe, 2025).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Attackers often prefer social engineering because it requires fewer and less specialized resources than technical hacking and can yield high rewards with minimal risk. Hybrid work culture and increased reliance on email and messaging apps are modern enablers, while generative AI can be a driver for more convincing fake communications.

Certain conditions facilitate social engineering attacks, including inadequate security awareness, widespread use of social media, and organizational cultures that do not prioritize cybersecurity. Human factors such as trust, authority, and urgency are exploited to persuade individuals and bypass security protocols.

Impacts: Fraud, theft, and the rise in identity-centric attacks parallels the increas in social engineering campaigns, primarily through phishing (ENISA, 2024).

Multi-hazard Context: Not applicable

Monitoring: Not applicable

Risk Management: Defending against social engineering requires implementing robust security policies and conducting regular awareness training[1]. From a technical standpoint, it is helpful to implement solutions such as email filters and AI-based detection systems. It is crucial to encourage a culture of security, mindfulness, and scepticism toward unsolicited communications (ITU, no date).

Despite its role in enhancing social engineering, artificial intelligence can also become a security tool, as it can play a crucial role in identifying and mitigating social engineering threats. Machine learning models can analyse patterns and anomalies in communication to detect phishing attempts and fraudulent activities (Odufian et al., 2025).

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Coordinating agency or organisation

International Telecommunication Union (ITU).

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TL0201 / TECHNOLOGICAL / Construction/Structural Failure

Building Collapse

Definition

Building collapse is the failure of load-bearing structural elements, causing a building to fall or fail catastrophically / catastrophic failure (adapted from US Department of Labor, no date).

Reference

US Department of Labor, no date. Structural Collapse Guide. Occupational Safety and Health Administration. https://www.osha.gov/emergency-preparedness/guides/structural-collapse Accessed 16 February 2025

Annotations

Synonyms

Catastrophic building failure, structure failure, built environment failure

Additional scientific description

All types of public and private buildings may be subjected to extreme events, caused, for example, by hurricanes, tsunamis, earthquakes, explosions, vehicle impacts, fires and human errors, or even terrorist attacks. Such events usually cause local damage to the structure of buildings, which can lead to a complete collapse. This is where the term progressive collapse comes in, understood as the process by which local damage sets in motion a chain of failures, leading to the collapse of the entire building or a large part of it. A progressive building collapse is always accompanied by serious personal and material losses. (Kokot & Solomos, 2012)

Six types of progressive collapse are identified, namely, pancake-, zipper-, domino-, section-, instability-, and mixed-type collapses. Each type of collapse was characterized in terms of failure propagation, outlining the propagating action resulting from the failure of a component and leading to the failure of further components (Starossek, 2007).

Progressive structural collapse is defined by the National Institute of Standards and Technology (NIST) as 'the spread of an initial local failure in a manner analogous to a chain reaction that leads to partial or total collapse of a building' (Ellingwood et al., 2007).

Metrics and numeric limits

The United Nations Educational, Scientific and Cultural Organization (UNESCO) lists 63 countries that have seismic design building codes (UNESCO, 2008).

Many countries have standards on progressive building collapse, these include European EUROCODE, Canadian National Building Codes and Swedish Design Regulations (Ellingwood et al., 2007).

Various other metrics include Floor Area Ratio (FAR) (Metropolitan Council 2015); design base shear (CMHA no date) and Seismic vulnerability index (SVI) (Kassem et al., 2019)

Key relevant UN convention / multilateral treaty

The 1954 Hague Convention for the Protection of Cultural Property in the Event of Armed Conflict. This international treaty, in times of peace, requires risk management plans to protect cultural assets when an urgent situation arises such as the failure of a structure and fire (UNESCO, 1954).

The International Labour Organization C167 - Safety and Health in Construction Convention, 1988 (ILO, 1988).

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The Sendai Framework for Disaster Risk Reduction 2015-2030 outlines seven clear targets and four priorities for action to prevent new and reduce existing disaster risks, including substantially reducing disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030 (UNDRR, 2015).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: weather-related structural failures typically result from rain/snow accumulations on roofs, hurricanes, tornadoes, landslides and even avalanches. Floods can also undermine foundations, leading to structural instability and potential collapse, as during the 2013 Central European when floods caused significant structural damage to buildings and infrastructure across Germany, Austria, and the Czech Republic. Landslides and associated movements of rock can impact the stability of foundations and cause structural failures. Extreme weather events such as cyclones, and severe storms can cause widespread damage to structures through high winds, storm surges, and debris impact, with damages worsened if the buildings are old or poorly maintained (Hain et al., 2023). Tsunami can inundate coastal areas and damage structures, and permafrost thaw and retreat affect the foundations of buildings leading to damages and even collapses. Earthquakes, such as the Turkiye-Syria earthquake in February 2023. sinkholes (which cannot easily be identified) and ground subsidence are also drivers of building collapse (WHO, 2019). Fire is another driver that can cause structural failure of steel and concrete buildings that can lead to the death of civilians and firefighters (Meacham et al., 2010; Ahmadi et al., 2020). Additionally, coastal erosion (Fouad et al., 2025) and issues such as building aging (Caredda et al., 2023) and heat island effects (Rotta, 2023) contribute to the risk of building collapse.

In many low- to middle-income countries building collapse has been attributed to weak foundations, substandard construction- al materials, poor material mixing by construction workers, excessive load on the strength of buildings and poor testing of building strength (Figueroa Fernandez, 2014). Building collapse is also caused by structural failures, poor supervision and workmanship, faulty design and disregard for approved drawings (Windapo and Rotimi, 2012). Additional factors include the absence of soil investigation before construction, lack of coordination between professional bodies and town planning authorities and inadequate enforcement of existing laws regulating physical development (Dimuna, 2010).

Terrorist activity may add additional hazards such as secondary devices, follow-on attacks and residual radiological, biological or chemical contamination (cf HIPs BI0602 & CH0903). Historically, terrorist activities that have resulted in collapsed structures include crashing commercial jets into the World Trade Towers in New York City (11 September 2001) and vehicular bombs, such as the one used at the Murrah Federal Office Building in Oklahoma City (19 April 1995) (OSHA, no date).

Impacts: The effects of building collapse include impacts on lives, livelihood and health, for example when asbestos is used in the building (cf HIP CH0202), as well as social, economic and environmental impacts (Babtunde, 2013). Since the United Nations International Strategy for Disaster Reduction launched its campaign kit for making cities resilient (UNDRR, 2010), the United Nations Office for Disaster Risk Reduction has been committed to making cities resilient and has engaged and published widely including sharing the ten essentials for making cities resilient (UNDRR, 2019). Engagement in this campaign is vital for enhancing the drivers for risk management with 'Essential Four: Pursue Resilient Urban Development and Design' which calls for integrating resilience into socio-economic development planning and infrastructure to safeguard development investments – which will help reduce the risks of building collapse (UNDRR, 2019).

The consequences of failure vary significantly from structure to structure, and may depend on:

- Nature of the hazard
- Properties of the structure
- Use/occupancy
- Location
- Time of day
- Time frame considered

On 24 April 2013 the collapse of the Rana Plaza building in Dhaka, Bangladesh which housed five garment factories killed at least 1132 people and injured more than 2500 (ILO, no date). This was due to additional stories being built that ignored the approved construction permits (Hira and Benson-Rea, 2017). Only five months earlier, at least 112 workers had lost their lives in another accident, trapped inside the burning fashions factory on the outskirts of Dhaka. Most of the factories do not meet the standards required by building and construction legislation. As a result,

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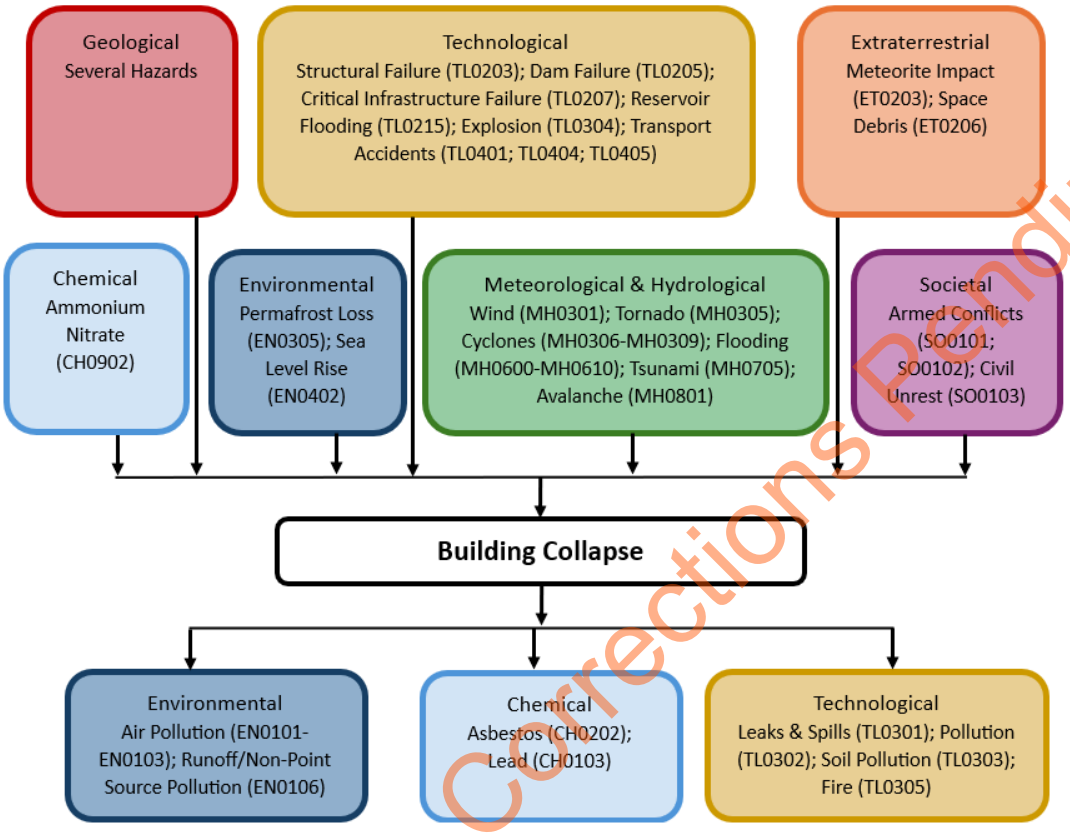
deaths from fire incidents and building collapses are frequent (ILO, no date).

Multi-hazard Context: The figure below summarises common interactions between building collapse and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



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Monitoring: Monitoring in building failure focuses on preventing malfunction by analysing anomalies in temperature control data. It can proactively optimize system performance, reduce downtime, and minimize personal costs (Mesa-Jimenez et al., 2021). The physical parameters commonly used to provide early warnings of building collapse during a fire include frequency, temperature, acoustic waves, displacement, and displacement velocity. It is essential to detect these parameters in real-time to deliver early warnings effectively (Li et al., 2023).

Risk Management: To mitigate the effects of progressive or disproportionate collapse, a quantitative and transparent approach focuses on enhancing structural robustness. This ensures that both new and existing structures can prevent collapse under abnormal loads. Structural robustness depends on system characteristics (e.g., strength, ductility, redundancy) and the type of abnormal loading (e.g., dynamic, impulsive). While sometimes referred to as "structural integrity," the latter term specifically means the structure's wholeness after an extreme event. Structural robustness strongly depends on redundancy, which is the ability of the structure to redistribute loads after damage to a single or a few members. Risk is considered implicitly in design by most codes in Table 5 by means of the building classification and design methods recommended for each class or risk category. Risk considerations are also included in some codes in order to define the overall design strategy (EN 1991-1-7, NBCC 1995, ASCE/SEI 7-16, UFC 4-023-03, GSA 2013). A major drawback in many codes is that risk is not considered in a very transparent or systematic way. The report on Building Regulation for Resilience – Managing Risks for Safer Cities, calls for mobilizing building code regulations for risk reduction (World Bank and GFDRR, 2026).

Databases have particular value in identifying factors that give rise to a disproportionate risk that only becomes clear from the analysis of larger-scale data as distinct from individual cases. Carreda proposes a novel database of building collapses which systematically collects information on the hazards, initial failures and their corresponding propagation mechanisms (Caressa et al, 2023).

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Coordinating agency or organisation

Not identified.

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TL0202 / TECHNOLOGICAL / Construction/ Structural Failure

Building, highrise, cladding

Definition

A building high-rise cladding fire hazard occurs when combustible materials such as cladding on a high-rise building greatly increases risk in the event of a fire and can have a catastrophic outcome (adapted from Rockpanel, no date)

Reference

Rockpanel, no date. What is a high rise or high-risk building? www.rockpanel.co.uk/applications/technical-support/firesafety/high-rise-buildings Accessed 25 January 2025.

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Annotations

Synonyms

Façade-related hazards, Tall building fire risk, Revestimiento (ES), Fassadenverkleidung (DE).

Additional scientific description

Building height is an important factor in fire safety. The National Fire Protection Association defines a 'high-rise building' as a building greater than 75 feet (25 m) in height where the building height is measured from the lowest level of fire department vehicle access to the floor of the highest occupiable story (OSHA, 2003). The definition of what constitutes a high-rise building differs for many European countries. For example, in Germany, high-rise buildings are those 22 m and above, in Belgium 25 m and above, and in the UK 18 m and above. Despite the exact limit, it is indisputable that risk increases with increasing building height (Rockpanel, no date).

Escaping from tall buildings is more difficult and takes longer than from a single-family house with one floor. Not only do highrise buildings have more inhabitants or people that work in them, but normal houses also have more escape routes (windows, doors) making escape easier when a fire occurs (Rockpanel, no date).

Composite panels were first developed as a cost-effective, lightweight building material that could be rapidly installed for external cladding or facades of industrial buildings. Following considerable development over recent decades, these panels are now widely used across a vast range of buildings. The main advantage of composite panels is that they are inexpensive, can be easily cut and shaped in any size or dimension, are lightweight, and have excellent insulation characteristics. The products also come with a wide variety of surface finishes to suit architectural designs. The issue of combustible composite panels now concerns both private residences and commercial offices and factories (Chen et al., 2019).

Recent high-profile building fires involving highly combustible external cladding panels in Australia as well as Dubai, China, and the United Kingdom have created a heightened awareness by the public, government, and commercial bodies of the need to act on the risks associated with non-compliant building structures (Chen et al., 2019). The history of fire incidents involving combustible external composite panels goes back many decades and includes well-documented events such as: the Knowsley Heights Fire in Liverpool UK, 1991; the Garnock Court Fire in Scotland, 1999; the Television Cultural Centre Fire in China, 2009; the Shanghai Apartment Fire in China, 2010; the Tecom Building Fire in Dubai, 2012; the Lacrosse Building Fire in Australia, 2014; The Torch in Dubai, 2015; The Address in Dubai, 2016; and Grenfell Tower in the UK, 2017 (Chen et al., 2019).

The Grenfell Tower fire broke out on 14 June 2017 in the 24-storey Grenfell Tower block of public housing flats in North Kensington, West London, United Kingdom. The London Metropolitan Police confirmed that 80 people died as a result. Prior to the incident, Grenfell Tower underwent a major renovation on the exterior of the building which included new windows, a heating system, and the installation of a new exterior cladding for insulation and rainscreen. The fire is believed to have been started by a refrigerator in a 4th floor apartment kitchen. The residents were in the apartment at the time and called the fire brigade. Despite firefighters arriving 6 minutes after the alarm, the fire managed to spread to the exterior cladding before the firefighters suppressed the kitchen fire. The flames spread at an alarming rate up the exterior cladding and the fire quickly became out of control. In addition, the exterior fire re-entered the building, trapping a significant percentage of residents inside the building (Chen et al., 2019).

In its report, the UK Ministry of Housing, Communities and Local Government stated that Aluminium Composite Material (ACM) cladding (and other metal composite material cladding) with an unmodified polyethylene filler (category 3) presents a significant fire hazard on residential buildings at any height with any form of insulation (Ministry of Housing, Communities and Local Government, 2020).

Metrics and numeric limits

As an example of Metrics and Numeric Limits: The UK Ministry of Housing, Communities and Local Government (MHCLG) has published 'Information for leaseholders and other residents about fire safety and fixing fire safety problems (also called remediation) including unsafe cladding' (MHCLG, 2024).

Key relevant UN convention / multilateral treaty

United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC calls on all Parties to reduce greenhouse gas emissions through low-carbon development strategies, including the adoption of sustainable building practices and climate-resilient materials.

Relevant ISO Standards Incorporated:

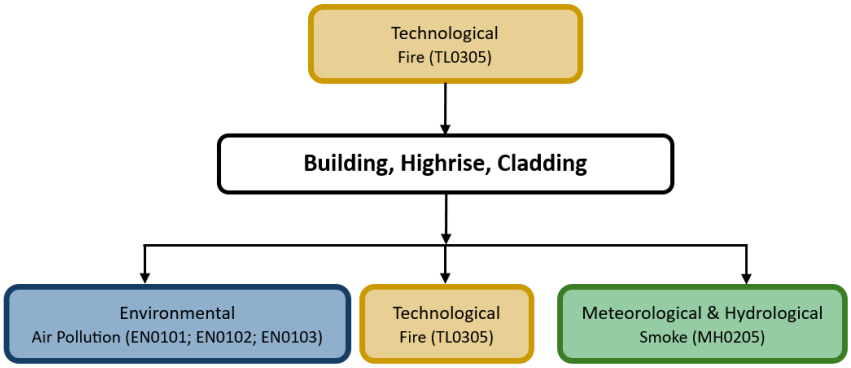
- ISO 5660 – Reaction-to-fire tests: Measures heat release rate and smoke production of façade materials.
- ISO 13785-1 – Intermediate-scale test for façades: Assesses fire behaviour of partial or component-level façade assemblies.
- ISO 13785-2 – Full-scale façade test: Evaluates vertical flame spread and overall fire propagation behaviour across complete façade systems.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: In October 2019, Phase 1 of the Grenfell Tower Inquiry reported on the role played by ACM cladding, fitted onto the exterior of the building. Sir Martin Moore-Bick, the Chairman of the Inquiry, found that the "principal reason why the flames spread so rapidly up, down and around the building" was the presence of combustible ACM cladding, "which acted as a source of fuel" (National Audit Office, 2020).

Impacts: Cladding with flammable material helps the fire to spread more quickly, resulting in the death of inhabitants and intoxication from smoke.

Multi-hazard Context: The figure below summarises common interactions between buildings, highrises & cladding and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: No Information Available

Risk Management: Appropriate exits, alarms, emergency lighting, communication systems, and sprinkler systems are critical for resident and employee safety. When designing and maintaining exits, it is essential to ensure that routes

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leading to the exits, as well as the areas beyond the exits, are accessible and free from materials or items that would impede individuals from easily and effectively evacuating (OSHA, 2003).

Since the tragedy at Grenfell Tower, the UK government's Building Safety Programme has focussed on identifying and advising on short-term interim and remedial measures for existing high-rise residential buildings with ACM cladding, while developing wider reforms for the future building safety regulatory system (Ministry of Housing, Communities and Local Government, 2020).

In the wake of the Grenfell Tower disaster, the Ministry of Housing, Communities and Local Government, UK, established the Building Safety Programme (the Programme) "to ensure that residents of high-rise residential buildings are safe, and feel safe from the risk of fire, now and in the future". While remaining clear that it is building owners who are responsible for ensuring the safety of their buildings, the Department has adopted an objective to "oversee and support the remediation of high-rise residential buildings that have unsafe aluminium composite material cladding". The Programme is designed to implement this objective, as well as to reform building regulations and the construction industry in light of flaws brought to light in the wake of the Grenfell tragedy (National Audit Office, 2020).

The Saudi Green Building Forum (SGBF) in Consultative Status with the Economic and Social Council; And scheme owner of saaf® Certification promotes sustainable and safe building practices through the official regional certification system saaf® (Sustainability Assessment Accreditation Framework). Regarding cladding principles, the saaf® certification mandates the exclusive use of non-combustible, low-emission, and locally adapted façade materials. This ensures that fire safety is fully integrated from the design stage through to final construction. The approach aligns with the principle of designing out risks to prevent hazards before they arise.

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Coordination agency or organisation

Not Identified

Preliminary – Corrections Pending

TL0203 / TECHNOLOGICAL / Construction/Structural Failure

Structural Failure

Definition

Structural failure corresponds to the exceedance of the ultimate limit state in many of the load-carrying elements, which compromises the structural stability of the building (Rossetto, 2013).

Reference

Rossetto, T., 2013. Building failure. In: Bobrowsky, P.T. (ed.), Encyclopaedia of Natural Hazards. Springer. link.springer.com/referenceworkentry/10.1007%2F978-1-4020-4399-4_27 Accessed 29 January 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Structural collapse, Structural defects, Progressive collapse.

Additional scientific description

Structural failure affects both above-ground and underground structures, including bridges, canals, viaducts, buildings, tunnels and pipelines. This exceedance may lead to a more widespread progressive collapse of the wider structure. Progressive structural collapse is defined by the National Institute of Standards and Technology (NIST) as the spread of an initial local failure in a manner analogous to a chain reaction that leads to partial or total collapse of a building (Ellingwood et al., 2007). Different types of progressive collapse have been referred to as pancake, zipper, domino, section, instability and mixed (Starossek, 2007).

Metrics and numeric limits

The United Nations Educational, Scientific and Cultural Organization (UNESCO) lists 63 countries with seismic design building codes, both members and non-members (UNESCO, 2019).

Many countries have standards on structural design and progressive collapse, these include the European EUROCODE (European Commission, 2020), Canadian National Building Codes (Government of Canada, 2015), and Swedish Design Regulations (Boverket, 2018).

Key relevant UN convention / multilateral treaty

The 1954 Hague Convention for the Protection of Cultural Property in the Event of Armed Conflict. This international treaty, in times of peace, requires risk management plans to protect cultural assets when an urgent situation arises such as the failure of a structure and fire (UNESCO, 1954).

The International Labour Organization C167 - Safety and Health in Construction Convention, 1988 (ILO, 1988).

The Sendai Framework for Disaster Risk Reduction 2015-2030 outlines seven clear targets and four priorities for action to prevent new and reduce existing disaster risks including to substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030 (UNDRR, 2015)

Examples of hazard drivers, impacts, and risk management

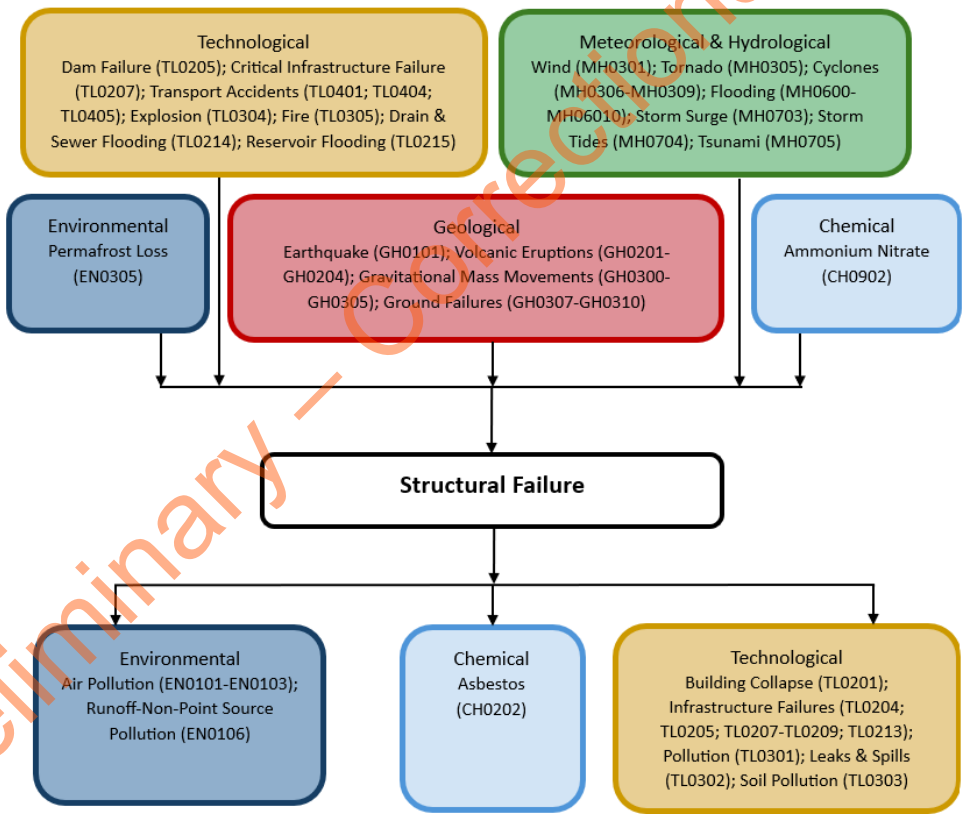
Hazard Drivers: The drivers of structural failure can include design defects by engineers or architects, incorrect or substandard construction materials, inspection failures to identify building and construction problems, as well as natural hazards or a combination of these drivers (Almarwae, 2017). Explosions, fire and transportation accidents may also result in structural failure

Three summary examples follow:

- The *Minneapolis bridge collapse* that occurred in 2007 is an example of a structural failure that resulted in people being killed and seriously injured. The root cause of this event was exceeding the original structural load-bearing design by retrofitting additional road transportation lanes at later stages and also the weight of road maintenance equipment on the bridge on the day of the failure (Hao, 2010).
- The *Heathrow tunnel collapse* in 1994 was attributed to the implementation of new project management frameworks, exceeded tolerances of tunnel deflection, inadequate repair to ground settlement, and lack of inspection and monitoring in the construction of the tunnel (Wood, 2000).
- The *Sasago tunnel collapse* took place in 2013, where a large section of the suspended ceiling panels fell onto moving traffic. This caused the deaths of nine people, and the failure was identified as the deterioration of the tunnel construction over time and a lack of routine maintenance (Fujino, 2018).

The forces generated by natural hazards such as earthquakes, cyclones or tsunamis can weaken or even cause the collapse of civil engineering structures that lack robustness. As urban areas become increasingly dense due to rapid urbanization, the potential risks to lives and property grow. The limited availability of land necessitates the construction of taller and more complex buildings, which are often more susceptible to lateral forces from wind and seismic activity. Consequently, understanding the impact of natural hazards on civil engineering structures remains a crucial area of research. (Jami et al., 2022).

Multi-hazard Context: The figure below summarises common interactions between structural failure and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



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Monitoring: Monitoring systems utilize sensor networks, data analysis, and AI-based predictive models to monitor real-time vibrations, cracks, and other structural anomalies. When abnormal signals are detected, it promptly issues alerts to enable preventive measures.

Advanced monitoring systems use sensor networks, data analytics, and AI-driven predictive models to continuously track real-time vibrations, cracks, and structural anomalies. Upon detecting abnormal patterns, the system classifies the risk level into three stages:

- Green (Safe): Normal conditions; routine monitoring continues.
- Yellow (Caution): Early signs of potential issues detected; preventive inspection is recommended.
- Red (Alert): Critical anomalies identified; immediate action is required.

This tiered alert system enables timely and effective preventive measures to ensure structural safety.

Risk Management: The Occupational Safety and Health Administration (OSHA) states that rescue workers and emergency responders may already have experience with entering collapsed structures resulting from construction catastrophes,

earthquakes, fire and weather-related structural failures. Weather-related structural failures typically result from rain/snow accumulations on roofs, hurricanes, tornadoes, landslides and even avalanches. Rescue workers and emergency responders also face the possibility of entering a structure that has collapsed following a terrorist attack. Terrorist activity may add additional hazards such as secondary devices, follow-on attacks and residual radiological, biological or chemical contamination (see chemical HIP on Chemical Warfare CH0903). Historically, terrorist activities that have resulted in collapsed structures include crashing commercial jets into the World Trade Towers in New York City (11 September 2001) and vehicle-borne bombs, such as the one used at the Murrah Federal Office Building in Oklahoma City (19 April 1995). Regardless of the root cause of the structural failure, rescue workers and emergency responders who enter a collapsed structure in order to perform their duties should be able to work safely (OSHA, no date).

The effects of building collapse include impacts on lives, livelihood and health as well as social, economic and environmental impacts. Since the United Nations International Strategy for Disaster Reduction launched its campaign kit for making cities resilient (UNDRR, 2010), the United Nations Office for Disaster Risk Reduction has been committed to making cities resilient and has engaged and published widely including sharing the ten essentials for making cities resilient (UNDRR, 2019). Engagement in this campaign is vital for enhancing the drivers for risk management with 'Essential Four: Pursue Resilient Urban Development and Design', which calls for integrating resilience into socio-economic development planning and infrastructure to safeguard development investments – which will help to reduce the risks of building collapse (UNDRR, 2019).

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Coordinating agency or organisation

Not identified.

Preliminary – Corrections Pending

TL0204 / TECHNOLOGICAL / Construction / Structural Failure

Bridge Failure

Definition

Bridge failure is the inability of a bridge, or its components, to perform as specified by its design and construction requirements (Wardhana and Hadipriono, 2003).

Note: This definition includes bridges that have totally collapsed, partially collapsed and those that experienced distress, such as exhibiting excessive deformation.

Reference

Wardhana, K. and F.C. Hadipriono, 2003. Analysis of recent bridge failures in the United States. Journal of performance of constructed facilities, 17:144-150.

Preliminary – Corrections Pending

Annotations

Synonyms

Bridge collapse.

Additional scientific description

Urbanisation leads to a continuous increase in demand for urban infrastructure, including bridges, highways and roads. The service life of infrastructure such as bridges is often shorter than expected due to natural phenomena and lack of sustainable concepts in design and construction. Bridge failures are one of the most severe infrastructure problems faced today and pose an imminent threat to life and property. This reinforces the need to conduct sustainability assessments and optimal risk mitigation measures. A key aspect of engineering failures is the relationship between failure and growth in engineering knowledge, which ensures the sustainable development of society.

Metrics and numerical limits

The estimated average annual bridge collapse rate in the United States is between 87 and 222 with an expected value of 128 (Cook, 2014)

The United States National Bridge Inventory, reports that on average, 188 million trips take place across a structurally deficient bridge per day in the USA. Between 1989 and 2000, a total of 503 bridges failed, resulting in 76 fatalities and 161 injuries. Of the 503 failures, 386 occurred during the bridge's service life rather than during construction (US Department of Transportation, 2020).

Key relevant UN convention / multilateral treaty

While there isn't a single UN convention specifically addressing bridge failures, several relevant treaties and agreements touch upon aspects related to infrastructure safety and resilience:

- United Nations Sustainable Development Goals (UNDESA, 2015).
- Sendai Framework for Disaster Risk Reduction 2015-2030: This framework emphasizes the importance of building resilient infrastructure and reducing disaster risk. It encourages countries to incorporate disaster risk considerations into infrastructure planning, design, and construction.
- Paris Agreement on Climate Change: Climate change increases the risk of extreme weather events (floods, hurricanes) that can impact bridge infrastructure. The Paris Agreement aims to strengthen the global response to the threat of climate change, which indirectly contributes to bridge safety.

- UN Convention on the Rights of Persons with Disabilities: This convention emphasizes the importance of accessible and inclusive infrastructure, including bridges, for people with disabilities.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: The collapse of bridges due to extreme weather events is a global issue. Earthquakes, erosion, floods, and other factors can cause bridge collapses, and especially when earthquakes and floods occur simultaneously or consecutively, they can pose a serious risk to bridges (Ganesh Prasad & Banerjee, 2012). The more common causes and mechanisms of bridge failures around the world may be classified into two groups: natural factors (flood, scour, earthquake, landslide, cyclones etc.) and human factors (poor design and construction method, collision, overloading, fire, corrosion, lack of inspection and maintenance etc.) (Choudhury and Hasnat, 2015).

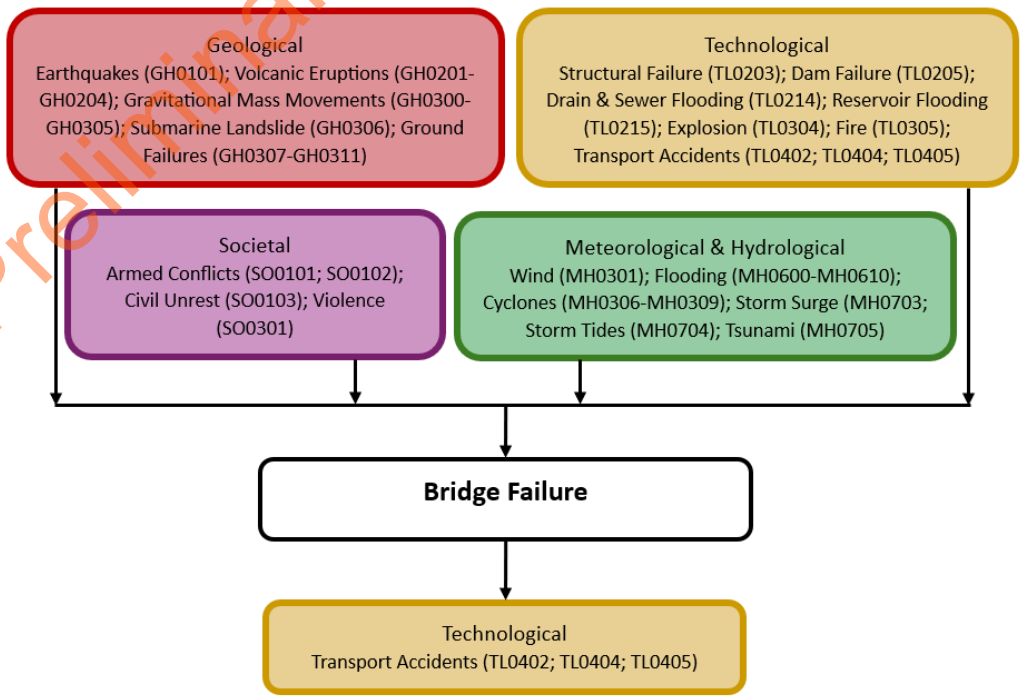
Earthquakes can cause severe structural damage or collapse of bridges, especially if they are not designed to withstand such forces. Similarly, landslides and associated movement of soil and rock can impact the stability of bridge foundations and approaches. Tsunamis can also inundate coastal areas and damage bridges. Scour, the erosion of soil around foundations by flowing water, can weaken support and lead to collapse. Heavy rainfall and river overflow can lead to significant flooding, which can undermine bridge foundations and cause structural failures. Hurricanes, cyclones, and severe storms can cause widespread damage to bridges through high winds, heavy rainfall, storm surges, and debris impacts, especially in coastal areas (Zhu et al., 2021). Climate change will also worsen the risks faced by bridges in the future (Markogiannaki, 2019)

Inadequate design calculations, use of substandard materials, faulty construction techniques, and errors in planning and execution can all contribute to failure. Insufficient or inadequate inspections, delayed or inadequate repairs, and neglect of routine maintenance can lead to deterioration and eventual failure. Fire and corrosion can also weaken structural elements over time. Exceeding the bridge's weight capacity can cause structural failure.

Collisions with vehicles, ships, or trains can severely damage the bridge structure while industrial accidents near the bridge, including spills of hazardous chemicals, and cyberattacks on bridge control systems may also cause bridge collapse or stop activities on bridges.

Impacts: Bridge collapses pose a significant risk to human life. By disrupting transportation networks, bridge collapse causes delays, traffic congestion, and increased transportation costs. This has economic and social impacts, leaving communities isolated, hindering emergency response, and disrupting essential services. Critical infrastructure, including bridges, is essential for national security and defence.

Multi-hazard Context: The figure below summarises common interactions between bridge collapse and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



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In August 2018, a large section of the Genoa Morandi bridge in Genoa Italy, collapsed resulting in 43 fatalities and required over 400 people to evacuate the surrounding area. The collapse led to widespread human displacement and created an economic disaster (Bellini and Calevo, 2019). Lack of maintenance work and/or bridge design, combined with excessive load and bad weather have been suggested as the reason(s) for the bridge collapse (Rymza, 2021; Villani, 2019).

Monitoring: Regular Inspections using various methods (visual, non-destructive testing) to identify potential problems early on and timely and effective repair and maintenance of identified deficiencies are also essential to maintain the bridge. A range of different monitoring techniques is available, including routine on-site visual inspections (possibly only conducted annually), continuous 24-hour camera surveillance, and non-destructive testing (NDT) methods such as fibre-optic grating sensors (Maaskant et al., 1997), polarimetric ground-based real aperture and radar system (Zou et al;, 2024), and microwave sensor interferometry (Zou & Alani, 2024).

Risk Management: Lessons identified from past bridge failures should inform the development of new materials, and more efficient forms of substructure and superstructure as well as new technology of construction are now leading to longer life spans of bridges (Choudhury and Hasnat, 2015). In response to recent bridge failures, research has had a growing focus on three aspects: the general situation and development trend of bridge failures; bridge safety based on structural monitoring and mechanism analysis; and risk assessment and control for sustainability and environmental health (Tan et al., 2020).

However, a bridge designed to current standards and properly maintained can still fail. This is largely due to the gap in research about how exceptional stresses and especially the interaction of different exceptional stresses can compromise bridge integrity. Wardhana and Hadipriono (2003) concluded in the United States, that hydraulics (flooding and flood-related debris strikes), collisions, and overloading failures accounted for 73.4% of bridge failures, with the vast majority caused by external events that subjected the bridges to conditions with which they could not cope. Bridge overload and lateral impact forces from trucks, ships and trains, resulted in 20% of total bridge failures.

To avoid bridge failures in the future, both design countermeasures and management guidelines should be implemented.

To improve bridge management, consideration should be given to social, environmental and economic sustainability (Tan et al., 2020). Environmental factors are one of the biggest risk factors engineers must consider in future bridge design. Climate change is a growing concern, with rising sea levels and increased frequency and severity of storms two examples of relevance to bridge design. Adapting to the potential impacts and loads caused by floods, storms and earthquakes are also key considerations for bridge resilience.

Engineering has an important role in the planning, construction and ongoing maintenance of bridges in order to support their function, safety and integrity. Incorporating cutting-edge design principles, advanced materials, and sophisticated analysis techniques, strict adherence to building codes and rigorous quality control throughout the construction process are essential to ensure good bridge design. Key considerations for bridge design include: surpasses national standards and guidelines, allows for higher flood levels than experienced historically, ensures the bridge can withstand significant loads and debris, and design bridges to withstand earthquakes in seismically active regions implement measures to reduce scour and erosion.

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Coordination agency or organisation

Not identified.

Preliminary – Corrections Pending

TL0205 / TECHNOLOGICAL / Construction/ Structural Failure

Dam Failure

Definition

Dam failure is the uncontrolled release of water due to structural collapse, foundation instability, or overtopping, posing risks to people and property downstream (ICOLD, 2023, mentioned in Moreno-Rodenas et al., 2025).

References

Moreno-Rodenas, A;, Mantilla-Jones, J. D., Valero, D., 2025. Age, climate and economic disparities drive the current state of global dam safety. Nature Water 3, 284-295 Age, climate and economic disparities drive the current state of global dam safety | Nature Water Accessed 15 March 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Dam break, Dam burst, Outburst, Dam breach.

Additional scientific description

A dam failure is a catastrophic incident characterized by:

- an uncontrolled release of impounded water;
- and/or by a total loss of integrity of the dam structure, its foundation, or abutments.

The term "dam" refers to any man-made barrier capable of impounding water, wastewater, or liquid-borne materials for storage or water control. A dam is considered to be 25 feet (7.62m) or more in height from either the natural stream bed or, if not across a stream channel, from the lowest elevation of the outer limit of the barrier to the maximum water storage elevation or has a storage capacity of 50 acre-feet (61,625m^3) or more. A large dam is a dam with a height of 15 metres or greater from lowest foundation to crest, or a dam between 5 metres and 15 metres impounding more than 3 million cubic metres (ICOLD, 2019). This definition is commonly adopted worldwide.

Dams are commonly categorised by a wide range of factors such as composition, height, and reservoir volume. Dams are typically constructed of earth, rock, concrete or tailings (chaff) from mining operations. As a function of upstream topography, even a small dam can impound or detain many millions of litres of water (acre-feet of millions of gallons (FEMA, 2017). The collapse or movement leading to a break in the dam could produce life-threatening flood situations due to the high velocities and large volumes of water involved. In the event of a dam failure, the potential energy of water stored behind the dam can cause significant damage to property and livelihoods, as well as injuries and loss of life for people downstream of the dam (FEMA, 2017).

The hazard potential classification system categorizes dam failure risks into three levels: LOW, SIGNIFICANT, and HIGH, with increasing adverse consequences (FEMA, 2004). Each level encompasses the consequences of the lower levels. The frameworks underscore that any dam failure, regardless of size, could endanger downstream life and property. They emphasize the unpredictability of such events and the potential for unexpected hazards, necessitating proactive risk management measures to mitigate risks effectively. (FEMA, 2017; ICOLD, 2023):

- The consequences of a low-hazard potential dam failure should result in no probable loss of human life and low economic and/or environmental losses.

- The consequences of a significant hazard potential dam failure should result in no probable loss of human life but can cause economic loss, environmental damage, disruption of lifeline facilities, or can impact other concerns.
- The consequences of a high-hazard potential dam failure will probably cause loss of human life.

Three summary examples of dam failures follow:

- ***Brumadinho dam disaster Brazil 2019***. On 25 January 2019, Córrego do Feijão's tailing dam at Brumadinho city breached, leading to at least 12 million cubic metres of tailing spread into Paraopeba River and the surrounding area, leaving more than 270 people dead and many missing, with major environmental impacts on the downstream catchment (Cambridge and Shaw, 2019; Thompson et al., 2020). This was the fifth tailings dam disaster to have occurred in the same region in an 18-year period and is considered the worst documented tailings dam failure to have occurred in the past 30 to 40 years. The failure at Brumadinho showed geotechnical similarities to that at Fundao in 2015, with the characteristic of all foundation zones predisposing the facility to an increased risk of basal liquefaction under increasing stress. Upstream construction, as well as management commitment to quality control and inspection and monitoring during operation, in addition to liquefaction and poor governance, are potentially considered for the failure of the Brumadinho dam (Thompson et al., 2020).
- ***Ajka Red Sludge Reservoir. On 4 October 2010***. The retaining wall of a caustic waste reservoir at the Ajka alumina plant near Kolontar, Hungary, collapsed releasing more than one million cubic metres of highly alkaline sludge containing toxic metals. The waste material flooded several nearby villages, resulting in 10 fatalities, 123 injured people, damage to buildings, and significant ecological and environmental impacts. Reports concluded that a check on the reservoir's stability and statics had not been performed by the relevant authorities (Ujaczki et al., 2015).
- ***Malpasset Dam, Fréjus, France. On December 2, 1959***, the Malpasset arch dam in southeast France suddenly failed, flooding the valley down to the sea, causing huge destruction and more than 400 casualties. Built from 1952 to 1954 for water supply and irrigation, the filling of the reservoir was delayed five years, and the failure occurred following a flash flood of the river the dam was closing. Post-failure studies and expertise during a trial revealed poor field investigations on a mica schist rock foundation crisscrossed by faults and poor management of the structure's construction. The failure was ascribed to uplift, moving a rock dihedron defined by a conspicuous fault and a tear along foliation (Duffaut & Larouzée, 2019).

A review of failure mode analysis and implications for current and future resilience of flood protection infrastructure in the United States has been undertaken (Primary and Secondary Causes of Dam Failure in the US, no date). Dam failures are classified by date, location, dam type, primary and secondary root causes, cost in year of incident, damage type, and fatalities. The International Commission on Large Dams (ICOLD) is an international non-governmental organisation dedicated to sharing professional information and knowledge of the design, construction, maintenance, and impact of large dams. ICOLD has 100-member national committees and over 10,000 individual members, (ICOLD, no date). ICOLD has created a World Register of Dams. This is a global database on dams, established based on the national inventories sent by member countries of ICOLD. The register is continuously updated and includes information on more than 55,000 dams. In addition to the dam register, ICOLD has developed a technical dictionary. Between 2000 and 2009, more than 200 notable dam failures happened worldwide (Jonkman & Vrijling, 2008).

Preliminary – Corrections Pending

Metrics and numeric limits

Many more works have supplemented the inventory since that time, including ICOLD Bulletin No. 194 "Tailings Dam Safety" (ICOLD 2023).

It identifies accidents and events by dam type and age and by cause of accident. It increases the designer's awareness of the range of unforeseen factors with, to some extent, their likelihood, and the sequences of events that can lead to disaster.

Key relevant UN convention / multilateral treaty

The Convention on the Protection and Use of Transboundary Watercourses and International Lakes (UNECE, 2013).

The United Nations Sustainable Development Goals (SDGs) (UNDESA, 2021). Water resources management and service are essential for sustainable development. Goal 6 focuses on the significance of water supply. SDG Goal 13 (climate action) mentions dam resilience to extreme weather. The SDGs can also be linked to the proper functioning of

dams as a source of municipal and rural water supply (Oyekanmi & Mbossoh, 2018).

The Sendai Framework for Disaster Risk Reduction, 2015-2030 (UNDRR, 2015).

UNDRR Guidelines for critical infrastructure (2023).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Dam failure is likely to occur due to seepage and internal erosion, poor foundation conditions, overtopping, static and seismic instability and other reasons such as subsidence, structural issues, external erosion and slope instability (Lyu et al., 2019). Dam failure may result from flash floods or river floods that can overwhelm the dam structure. Earthquakes may cause structural damage or failure. Prolonged droughts can reduce water levels, affecting the dam's functionality and stability. Landslides into reservoirs can create waves that overtop dams. Extreme weather events such as hurricanes, cyclones, and other severe weather can impact dam integrity.

Contaminants from industrial activities can weaken dam materials and structures while accidental releases of hazardous chemicals can cause structural damage or compromise the dam's integrity. Incidents involving nuclear or radiological materials can have catastrophic impacts on dam safety. Accidents on or near dams can pose significant hazards, especially if they involve vehicles transporting hazardous materials. Design flaws and poor maintenance (inadequate inspections and repairs) can lead to undetected structural weaknesses while mistakes in managing water levels, especially during extreme weather events, can lead to overtopping or structural stress. Accidental damages caused by construction activities near dams or deliberate damage to the dam's structure or operational systems can cause failure.

Impacts: Dam failure can lead to rapid draining of the reservoir, causing erosion and habitat destruction upstream. Downstream, the sudden release of water can result in catastrophic flooding, endangering lives and property.

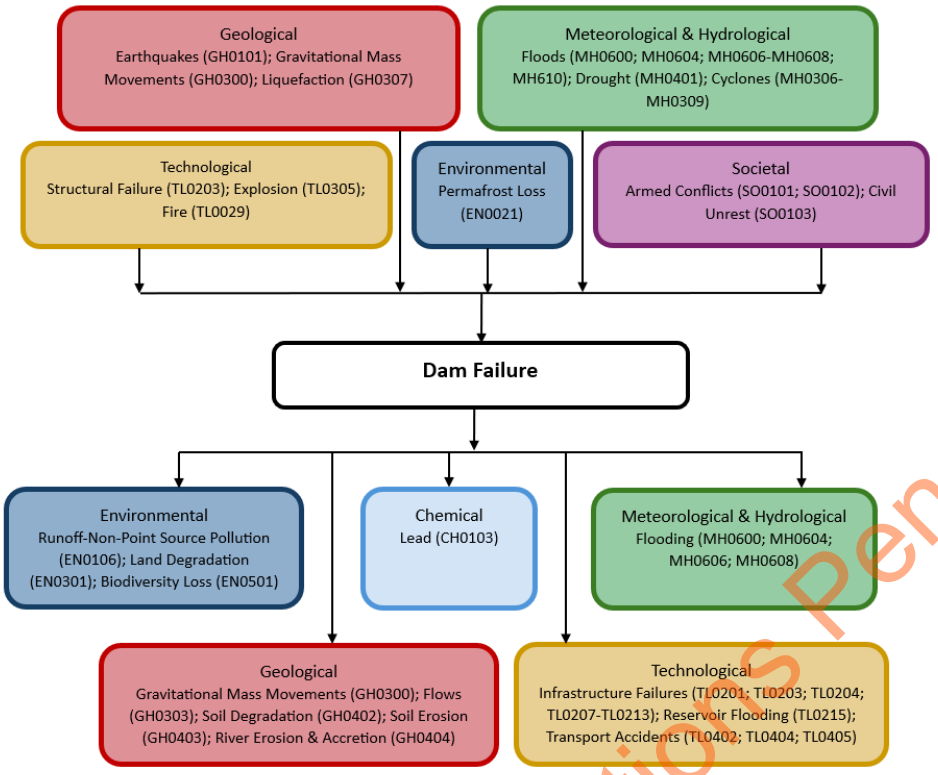
Dam safety agencies have generally adopted a common tiered hazard classification structure including Low, Significant, and High hazard potential classifications. Dam safety engineers commonly use the hazard potential classification system as a prioritisation tool to focus attention on those dams with the greatest potential consequences of failure.

Dam failures can damage various infrastructures such as transportation, electricity, communication, and water systems, and can cause surface and groundwater contamination as well as air pollution. Additionally, floods resulting from dam failures can trigger secondary disasters, including landslides, soil erosion, and ground subsidence (FEMA, 2012).

Risk creep also known as hazard creep is a term used to describe the gradual increase in anticipated consequences of a dam failure due to infrastructure development either along the drainage below a dam or within the reservoir area upstream. Although the physical condition of the dam may not change, hazard creep can result in an immediate adverse impact on the overall risk profile of a dam because the consequence component has increased. For example, new residential development within the dam breach floodplain could raise the status of a dam from one with a low hazard potential to one with significant or high hazard potential. Hazard creep can require costly dam safety modifications to address design deficiencies, such as increasing spillway capacity to safely route the probable maximum flood (for high-hazard potential dams) (FEMA, 2017).

Multi-hazard Context: The figure below summarises common interactions between dam failure and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the ‘Hazard drivers’ and ‘Impacts’ sections above.

Preliminary – Corrections Pending



Monitoring: Compressive and regular deformation of a dam can be monitored using satellite Interferometric Synthetic Aperture Radar (InSAR) (Wang et al., 2023).

Risk Management: Following recent dam failure disasters, many countries put safety first and invest in prevention largely using Dam Safety Laws. This includes applying the UNECE's safety standards 'Safety Guidelines and Good Practices for Tailings Management facilities' (UNECE, 2016). Such guidelines, developed by the Joint Expert Group on Water and Industrial Accidents under UNECE's Industrial Accidents Convention and Water Convention, provide authorities with recommendations for practical applications to limit accidents and the severity of their consequences (UNECE, 2016).

The Conference of the Parties to the United Nations Economic Commission for Europe Industrial Accidents Convention sets the future direction for technological disaster risk reduction towards 2030 (UNECE, 2018).

For what concerns the relation between Flood risk and Dam Failure, the FEMA P-1085 (2023) is the main resource for risk modelling and flood mapping related to dams. It provides guidelines for creating maps to visualize flood risks from dam incidents or failures. These maps help assess hazards, support emergency action planning, and guide resource allocation to protect lives and property. It incorporates advanced modelling, GIS tools, and collaborative input from stakeholders, integrating these maps into emergency plans to enhance community preparedness.

An early warning system (EWS) is a critical tool for preventing or mitigating potential disasters caused by dam failures. Pre-event planning focuses on assessing risks, developing appropriate plans, and implementing mitigation measures and preparedness activities to reduce risks effectively. Risk assessment involves analysing threats and vulnerabilities to exposed people and assets to estimate potential losses. Planning actions include efforts by federal, state, local, and tribal entities to support long-term risk reduction, emergency response, and post-event recovery. These activities strengthen community resilience and response capacity, minimizing the impact of dam failures (FEMA, 2017).

Preliminary – Corrections Pending

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Preliminary – Corrections Pending

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Coordination agency or organisation

Not identified.

Preliminary – Corrections Pending

TL0206 / TECHNOLOGICAL / Construction/Structural Failure

Supply Chain Failure

Definition

Supply chain failure refers to an event in the supply chain that disrupts the flow of materials on their journey from initial suppliers through to final customers (Walters, 2007).

Reference

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Preliminary – Corrections Pending

Annotations

Synonyms

SCM failure. Logistics disruption. Distribution system breakdown. Supplier Risk Management (SRM); Supplier Collapse; Third-party collapse; Third-party failure; Business interruption

Additional scientific description

There is no single best definition of the term supply chain (UNECE, 2016). Supply chains have been defined as a network of connected and interdependent organizations mutually and co-operatively working together to control, manage and improve the flow of materials and information from suppliers to end users.

Failure of supply chains reduces resilience in disaster risk management. In today's highly competitive industries, the reality facing most prime or focal manufacturing organisations around the world is one where resources have been reduced, inventory has been drained, technology spending curtailed, and processes that are not core to an organisation's business have been scaled back and/or outsourced. In competitive global marketplaces, prime manufacturers cannot afford to have any area of their operations compromised. Supply chain operations need to be robust and resilient in order to retain and increase market share. Supply chain failure is a phenomenon that can potentially cause major issues for many organisations, especially when failure becomes persistent (Karsten, 2018).

International trade is vital to the world economy. Businesses that trade internationally are supported by interlinked global supply chains, which are vital to their competitiveness. But as some recent events highlight, these dynamic, complex systems are vulnerable to numerous risks. Because of their interconnectedness, even small, localised events can escalate rapidly and cause significant disruptions (WEF, 2014). Supply chain performance is critical to business success; hence, supply chain disturbances could have a significant effect on the availability of goods and services as these are reduced; additionally, the cost of goods may; demand may increase dramatically, for example for building materials; and might lead to, for example, panic buying. These impacts may lead to a sudden increase in demand, having the potential to disrupt entire supply chains (Dulam et al., 2020).

Critical infrastructure relies on supply chain supplies in order to provide essential services for community, national, regional and global resilience. This includes water, transportation and telecommunications infrastructure, educational facilities, hospitals and other health facilities that ensure all remain safe, effective and operational during and after disasters in order to provide lifesaving and essential services.

Metrics and numeric limits

Various metrics exist and these include:

- The Lead Time Index measures on-the-ground trade logistics performance, helping national leaders, key policymakers, and private sector traders understand the challenges they and their trading partners face in reducing logistical barriers to international commerce. (World Bank no date)
- Port Congestion Index (PCI) is a metric that measures the level of congestion at a port, offering a comprehensive view of how efficiently a port is operating (Spire Maritime Docs no date),
- Inventory Turnover Ratio is a measure of the number of times inventory is sold or used in a time period such as a year (Oracle Net Suite, 2024)
- On-time delivery, where a 25% drop in on-time delivery indicates a significant decline in a company's ability to meet promised delivery deadlines. This metric, often referred to as On-Time Delivery (OTD), is a key performance indicator (KPI) for businesses, particularly in e-commerce and manufacturing, and reflects how well they are fulfilling customer orders within the expected timeframe. (McKinsey and Company, 2019)

Key relevant UN convention / multilateral treaty

The Sendai Framework for Disaster Risk Reduction 2015-2030 (UNDRR, 2015).

Other multi-lateral treaties such as Basel III (Bank for International Settlements) are cross-sector. For example, Basel III 2017-2028 is an internationally agreed set of measures developed by the Basel Committee on Banking Supervision in response to the financial crisis of 2007-09. The measures aim to strengthen the regulation, supervision, and risk management of banks. It sets international standards and minimums for bank capital requirements, stress tests, liquidity regulations, and leverage, with the goal of mitigating the risk of bank runs and bank failures and any cascading impacts (BIS, no date)

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Over recent decades, supply chains have globalised, specialised and become leaner or just-in-time. They are more efficient, and less risky in certain areas, but potentially more exposed to a breakdown of cooperation. With economic instability, food insecurity, technology reduced availability affecting for example., semiconductors, and failure to provide adequate medical supplies in crises supply chain failures are more impactful.

Supply chain managers have encountered many shocks such as the Great East Japan Earthquake and tsunami, Thailand's flooding, the Eyjafjallajökull volcano in Iceland, the maritime piracy upsurge, (Doherty and Botwright, 2020) and the Coronavirus disease (COVID-19) pandemic (WHO, no date), all of these shook supply chains across entire regions.

Impacts: A 2012 World Economic Forum survey of supply chain professionals ranked disruptions most likely to provoke significant and systemic effects on supply chain networks. The list included pandemics, natural hazards, extreme weather, conflict, demand shocks, ICT breakdowns, and export/import restrictions such as export restrictions currently being placed on medical supplies. Triggers of supply chain disruption are hard to predict, and sometimes neither controllable nor influenceable. The robustness of networks is paramount to ensuring demand can be met with supply even in extraordinary times (Doherty and Botwright, 2020).

Large-scale natural hazards such as earthquakes and tsunamis can disrupt the entire regional supply chain. As supply chains become more globalized and complex, their vulnerabilities increase. For example, when a flood causes logistical disruptions and a pandemic simultaneously leads to a shortage of labour, recovery of the supply chain becomes even more challenging. Additionally, in complex supply chains, a single disruption can have a cascading effect on other parts, which can accelerate supply chain failure in a multi-hazard context (Ye & Abe, 2012).

Multi-hazard Context: The figure below summarises common interactions between supply chain failure and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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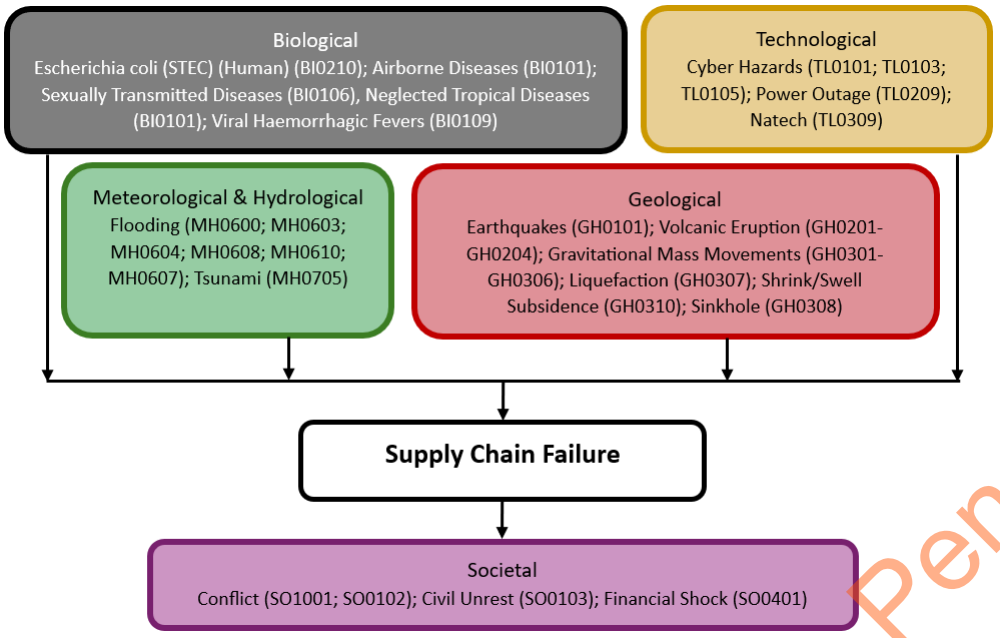

Monitoring: No information Available

Risk Management: It is clear that a supply chain problem can harm critical national infrastructure, national resilience, health, banking and wider sectoral resilience; and even a company's ability to deliver its services or goods and could impact its viability. The Sendai Framework has a strong emphasis on disaster risk management as opposed to disaster management. The scope of disaster risk reduction has been broadened significantly to focus on both natural and man-made hazards and related environmental, technological and biological hazards and risks (UNDRR, 2015).

Following large-scale and catastrophic disasters, local organisations integrate with other responding organisations to form hastily developed disaster relief supply chain networks. Unfortunately, even where sound supply chain management practices are used, supply networks have encountered diverse levels of resilience and adequate disaster relief performance has remained elusive (Day, 2014).

The private sector is a critical participant in the creation of risk-resilient societies. ARISE, the Private Sector Alliance for Disaster Resilient Societies, is a network of private sector entities led by the UN Office for Disaster Risk Reduction (UNDRR). The Philippine Disaster Resilience Foundation (PDRF) provides an example of how ARISE and the impact of its work on supply chain support after the 2013 typhoon. The PDRF reported on a public-private partnership for a livelihood seeding program in a post-disaster context working in a post-disaster scenario in the Province of Leyte:

- The PDRF designed an early recovery programme with national government agencies, local government units, and international non-governmental organisations – leveraging the capabilities of each organisation in support of micro- and small enterprises and the normalisation of the local supply chain.
- The Post Disaster Needs Assessment provided programme partners with a way forward to support affected communities and livelihood outside of relief packages of 'starter kits' including items such as kitchenware, gas stoves and cooking equipment for food business owners and grocery stocks, bags of rice and weighing scales for *sarisari* storeowners. In helping to jumpstart early recovery, people were provided with the opportunity to help themselves and regain their businesses. They also reported that another benefit of this early recovery activity was the stabilising of market prices for basic commodities and deterring opportunists that prey on the vulnerability of the community's situation.
- Two months after the Post Disaster Needs Assessment beneficiaries were able to group into clusters/sectors (dressmaking, eatery/*carinderia* operations, delicacy making, and food vending). Sub-sector members were able to gather, discuss updates on their businesses, identify potential markets, and update themselves with market trends (UNDRR, no date).

Risk managers, organisational resilience and business continuity leads should be aware of previous disruptions and address the five priority strategies to improve control measures further: risk quantification, scenario planning, data sharing, trusted networks, and multi-stakeholder input to legislation (Doherty and Botwright, 2020).

The Sendai Framework mentions strengthening the resilience of supply chains as an important goal for disaster risk reduction (UNDRR, 2015). EWS helps to identify risks that could impact the supply chain by providing early warnings before a disaster occurs, allowing for preparedness and response measures. Additionally, when disaster warnings are

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provided, businesses can take steps to minimize the impact on their supply chains, and communities can develop evacuation plans, making EWS extremely important.

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Coordination agency or organisation

Not Identified.

Preliminary – Corrections Pending

TL0207 / TECHNOLOGICAL / Construction/ Structural Failure

Critical Infrastructure Failure

Definitions

Critical Infrastructure failure is defined as the failure in one or more of the physical structures, facilities, networks and other assets which provide services that are essential to the social and economic functioning of a community or society (UNGA, 2016).

Critical Infrastructures as described in the ANNEX of (CER - DIRECTIVE (EU) 2022/2557 of the European Parliament and of the council) can be defined as: Energy (e.g., Electricity, District heating and cooling, Oli, Gas, Hydrogen); Transport (Air, Rail, Water, Road, Public Transport); Banking; Financial market infrastructure; Health; Drinking water; Wastewater; Digital Infrastructure; Public administration; Space (European Parliament 2022).

Preliminary - Corrections Pending

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European Parliament 2022, Directive (EU) 2022/2557 of the European Parliament and of the Council of 14 December 2022 on the resilience of critical entities and repealing Council Directive 2008/114/EC. https://eur-lex.europa.eu/eli/dir/2022/2557/oj Accessed 16 December 2024.

Annotations

Synonyms

Not identified.

Additional scientific description

The criteria for the determination of the significance of a disruptive effect that can lead to a failure (CER - DIRECTIVE (EU) 2022/2557 of the European Parliament and of the council)

- The number of users relying on the essential service provided by the entity concerned
- The extent to which other sectors and subsectors as set out in the Annex depend on the essential service in question
- The impact that incidents could have, in terms of degree and duration, on economic and societal activities, the environment, public safety and security, or the health of the population
- The entity's market share in the market for the essential service or essential services concerned

- The geographic area that could be affected by an incident, including any cross-border impact, taking into account the vulnerability associated with the degree of isolation of certain types of geographic areas, such as insular regions, remote regions or mountainous areas

In Article 13 "Resilience measures of critical entities", CER directives lay down obligations for critical entities aimed at enhancing their resilience and ability to provide services in the internal market, and are offering the resilience philosophy concept that needs to be followed by critical infrastructure operators:

- Prevent incidents from occurring, duly considering disaster risk reduction and climate adaptation measures.
- Ensure adequate physical protection of their premises and critical infrastructure, duly considering.
- Respond to, resist and mitigate the consequences of incidents, duly considering the implementation of risk and crisis management procedures and protocols and alert routines.
- Recover from incidents, duly considering business continuity measures and the identification of alternative supply chains, in order to resume the provision of the essential service.
- Ensure adequate employee security management, such as setting out categories of personnel who exercise critical functions, establishing access rights to premises and laying down appropriate training requirements and qualifications.

Raise awareness about the measures referred to in points (a) to (e) among relevant personnel, duly considering training courses, information materials and exercises.

Paragraph 18 of the Sendai Framework on Disaster Risk Reduction 2015-2030 calls for the global target of:

d. Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030 (UNDRR, 2015).

The Sendai Framework identified as priorities for action (Priority 4: Enhancing disaster preparedness for effective response and to 'Build Back Better' in recovery, rehabilitation and reconstruction) this example of reducing critical infrastructure hazards and failures:

c. To promote the resilience of new and existing critical infrastructure, including water, transportation and telecommunications infrastructure, educational facilities, hospitals and other health facilities, to ensure that they remain safe, effective and operational during and after disasters in order to provide live-saving and essential service (UNDRR, 2015).

The United Nations General Assembly report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction, defines the following of relevance to critical infrastructure failure:

- "A sudden onset disaster is one triggered by a hazardous event that emerges quickly or unexpectedly. Sudden onset disasters could be associated with, e.g., earthquake, volcanic eruption, flash flood, chemical explosion, critical infrastructure failure, transport accident" in the Disaster impact definition (UNGA, 2016).
- "Corrective disaster risk management activities address and seek to remove or reduce disaster risks which are already present, and which need to be managed and reduced now. Examples are the retrofitting of critical infrastructure or the relocation of exposed populations or assets" in the Disaster risk management definition (UNGA, 2016).
- "Examples of physical assets that are the basis for calculating direct economic loss include homes, schools, hospitals, commercial and governmental buildings, transport, energy, telecommunications infrastructures and other infrastructure; business assets and industrial plants; and production such as crops, livestock and production infrastructure. They may also encompass environmental assets and cultural heritage" in the Economic loss definition (UNGA, 2016).
- "Technological hazards originate from technological or industrial conditions, dangerous procedures, infrastructure failures or specific human activities. Examples include industrial pollution, nuclear radiation, toxic wastes, dam failures, transport accidents, factory explosions, fires and chemical spills. Technological hazards also may arise directly as a result of the impacts of a natural hazard event" in the Hazard Definition (UNGA, 2016).
- "The medium and long term rebuilding and sustainable restoration of resilient critical infrastructures, services, housing, facilities and livelihoods required for the full functioning of a community or a society affected by a disaster, aligning with the principles of sustainable development and 'build back better', to avoid or reduce future disaster risk" in the reconstruction definition (UNGA, 2016).

Critical infrastructure is essential for community, national, regional and global resilience. It includes water, transportation

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and telecommunications infrastructure, educational facilities, hospitals and other health facilities that ensure that all remain safe, effective and operational during and after disasters in order to provide lifesaving and essential services.

Historically, critical infrastructure has primarily faced risks from accidents and natural hazards. However, in today's increasingly digital and interconnected world, the range of threats to its resilience has expanded significantly. It is expected that by 2025, 30% of critical infrastructure organizations will suffer security breaches severe enough to disrupt operations. In response, governments are placing greater emphasis on protecting critical assets, particularly those spanning international borders. Over the past five years, cyberattacks on critical infrastructure have risen, resulting in significant impacts on public safety, economic stability, and national security. Threat actors are employing advanced methods to exploit networks, software vulnerabilities, and even launch physical attacks on cyber systems (Gallagher, 2023). According to the World Economic Forum, cyberattacks on critical infrastructure were ranked among the top 5 global risks with the greatest potential impact in 2023 (WEF, 2023).

Examples of recent events leading to critical infrastructure failure include:

- **Texas Power Grid Failure (2021):** A severe winter storm in February 2021 led to unprecedented cold temperatures across Texas. The state's power grid, managed by the Electric Reliability Council of Texas (ERCOT), was not adequately winterized to handle such extreme conditions. This resulted in widespread equipment failures and a significant reduction in power generation capacity. The power grid failure left millions of Texans without electricity, heat, and water for several days. The disruption caused at least 246 deaths, extensive property damage, and economic losses (Madhavan & Rajamani, 2022).
- **Western European Floods (July 2021):** Extreme precipitation caused by a persistent low-pressure system led to record-breaking water levels in parts of Germany, Belgium, and the Netherlands. The floods resulted in severe damage to critical infrastructure, including bridges, sewage systems, schools, and hospitals. In Germany and Belgium, many infrastructure assets were either severely damaged or destroyed. The floods caused at least 220 casualties and significant economic losses (Koks et al., 2022).
- **Baltic Sea Pipeline and Communication Cable Incidents (Autumn 2023):** Incidents affecting a pipeline and communication cables in the Baltic Sea, which are still under investigation, highlighted the vulnerabilities of critical infrastructure to potential sabotage or accidents (Bueger & Liebetrau, 2023).

Metrics and numeric limits

The Sendai Framework Monitor calls for all UN member states to report on the agreed global targets. Of note is Global Target D: Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030 (UNDRR, 2017).

- D1 (compound) Damage to critical infrastructure attributed to disasters.
- D2 Number of destroyed or damaged health facilities attributed to disasters.
- D3 Number of destroyed or damaged educational facilities attributed to disasters.
- D4 Number of other destroyed or damaged critical infrastructure units and facilities attributed to disasters. The decision regarding those elements of critical infrastructure to be included in the calculation will be left to the Member States and described in the accompanying metadata. Protective infrastructure and green infrastructure should be included where relevant.
- D5 (compound) Number of disruptions to basic services attributed to disasters.
- D6 Number of disruptions to educational services attributed to disasters.
- D7 Number of disruptions to health services attributed to disasters.
- D8 Number of disruptions to other basic services attributed to disasters. The decision regarding those elements of basic services to be included in the calculation will be left to the Member States and described in the accompanying metadata.

WHO technical guidance notes on Sendai Framework Reporting by Ministries of Health (WHO, 2020).

Key relevant UN convention / multilateral treaty

Sendai Framework for Disaster Risk Reduction 2015-2030 (UNDRR, 2015).

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Examples of hazard drivers, impacts, and risk management

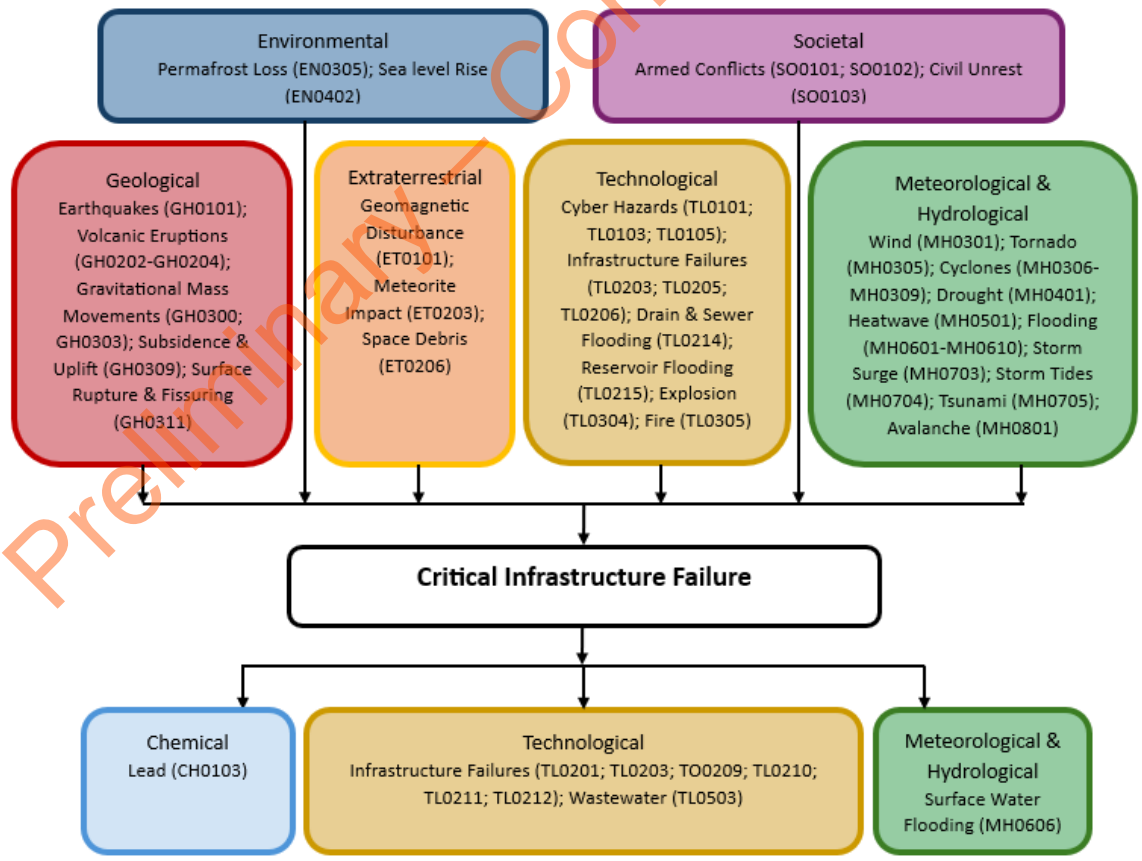
Hazard Drivers: Climate change and the increasing frequency of natural hazards pose significant challenges to infrastructure. Flooding, geomagnetic and convective storms, as well as wildfire damage, are causing greater loss severity and disrupting supply chains (Gallagher, 2023).

Heavy rainfall and river overflow can lead to significant flooding, which can damage or overwhelm infrastructure. Similarly, hurricanes, cyclones, and severe storms can cause widespread damage to infrastructure (Mühlhofer et al., 2023). Earthquakes can cause structural damage or failure of critical infrastructure while landslides can impact the stability and functionality of infrastructure, ash and lava flows from volcanic eruptions can disrupt and damage infrastructure and tsunamis can inundate coastal areas and damage infrastructure. Droughts and prolonged periods of low rainfall can reduce water levels, affecting the operation of dams and other water-related infrastructure.

Failures in industrial facilities can release hazardous materials, impacting nearby critical infrastructure. This includes accidental releases of hazardous chemicals, such as ammonium nitrate (see HIP CH0902) that can cause structural damage or compromise the integrity of infrastructure, and incidents involving nuclear or radiological materials that can have catastrophic impacts on infrastructure safety. Incidents involving the transportation of hazardous materials can also pose risks to nearby infrastructure. Poor maintenance and oversight, design flaws, or ageing infrastructure can lead to failures. Deliberate terrorist attacks and cybersecurity threats can also disrupt the operation and safety of critical infrastructure systems.

Impacts: Failures in critical infrastructure often lead to cascading effects. For instance, during the 2021 floods in Western Europe, communication systems in Germany's Ahr Valley were disrupted, and steep valley roads became impassable, making it extremely difficult to evacuate hospitals and care facilities. When critical infrastructure fails, it disproportionately affects socially vulnerable groups such as the elderly, the sick, or those living in poverty (UNU, 2024).

Multi-hazard Context: The figure below summarises common interactions between critical infrastructure failure and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: Monitoring critical infrastructure for potential failures involves a multifaceted approach, including real-time data

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collection, advanced analytics, and proactive response measures. Many systems exist and depend on the infrastructure at risk.

Risk Management: CER directives (European Parliament, 2022) are updating the previous version of them (Directive 2008/114/EC) and have as objectives to:

- Lay down obligations on Member States to take specific measures aimed at ensuring that services which are essential for the maintenance of vital societal functions or economic activities
- Lay down obligations for critical entities aimed at enhancing their resilience and ability to provide services in the internal market
- Establish rules on the supervision of critical entities, on enforcement and for the identification of critical entities of particular European significance establishes common procedures for cooperation and reporting on the application of this Directive
- Lay down measures with a view to achieving a high level of resilience of critical entities in order to ensure the provision of essential services within the Union and to improve the functioning of the internal market.

An example from the Energy infrastructures domain, of an EU-based research program with applications in real-life practice that aligned and strengthened these directives was SecureGas (Securing the European Gas Network, https://www.securegas-project.eu/):

SecureGas promoted CIs resilience through the adoption of key attributes that support a system-thinking approach. The Gas CI network was analysed at system level, meaning that this wide complex system has been studied from the production phase to the transmission one, till the distribution to the users, considering also multi-sectoral and transboundary interdependencies. Moreover, adopting an all-hazards risk-based approach, it targeted the establishment of the resilience concept throughout the entire life cycle of the Gas CI network, from the design phase to its operation and maintenance. As such, the main principles of a resilience-based asset management framework have been elaborated to pursue a comprehensive risk-based approach for managing threats and vulnerabilities. Security, safety, technical and environmental aspects have been assessed, providing documented guidance for the selection of appropriate alternatives to be examined during the various phases of infrastructure projects. In line with the above, an innovative all hazards & all threats risk assessment study of a pipeline hub (including compressor stations) has been performed in the SecureGas project.

The project contributed, in practice, to the update of the CER directives, by adopting an approach demonstrating how new threats, like cyber-attacks, as well as unconventional disruptions of critical infrastructures, will be incorporated in an innovative tool for security assessment and integrated into more conventional risk assessment approaches. The outcomes of these drivers and risk management knowledge and tools were the base for expanding this philosophy and contributing to the updated CER directives by spreading the type of studied hazards (hybrid) and including new types of infrastructures (subsea infrastructures).

The Sendai Framework is the successor instrument to the Hyogo Framework for Action (HFA) 2005-2015: Building the Resilience of Nations and Communities to Disasters. The HFA was conceived to give further impetus to the global work under the International Framework for Action for the International Decade for Natural Disaster Reduction of 1989, and the Yokohama Strategy for a Safer World: Guidelines for Natural Disaster Prevention, Preparedness and Mitigation and its Plan of Action, adopted in 1994 and the International Strategy for Disaster Reduction of 1999 (UNDRR, 2015).

The Sendai Framework has a significantly strong emphasis on disaster risk management as opposed to disaster management. The scope of disaster risk reduction has been broadened significantly to focus on both natural and man-made hazards and related environmental, technological and biological hazards and risks. Health resilience is strongly promoted throughout (UNDRR, 2015).

Two examples from the health domain are shared below to show how leadership at a UN level engages to deliver approaches to help at local and national levels to reduce critical infrastructure failures:

Making health facilities safe in emergencies: In emergencies, disasters and other crises, the lives and well-being of the affected population must always be protected, particularly in the minutes and hours immediately following impact or exposure as time is of the essence in saving lives. The ability of health services to be delivered by critical infrastructure such as health facilities without interruption in these situations is a matter of life and death. For a safe health facility to remain intact, accessible and functioning at maximum capacity before, during and immediately following an emergency or disaster, it relies on key factors: health infrastructure that can resist exposures and forces from all types of hazards (e.g., retrofitted towards disaster risk reduction); medicine and medical equipment that are essential, accessible and protected from damage from all hazards (including climate change impacts); community

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infrastructure and critical services (such as water, food, electricity and medical supplies) that are available to support the delivery of health services; and health personnel who can provide medical assistance in safe and secure settings where and when they are most needed (WHO, no date).The World Health Organization (WHO)'s safe health facilities' programme supports Member States to: develop national policies and regulations on making health facilities safe from disasters; protect the lives of the occupants of a health facility; protect the economic investment as well as the functionality of both new and existing health facilities and those identified as priorities (e.g., hub hospital) within the health services network; compile, organise and monitor the implementation of policies as well as national and international regulations on safe health facilities; and make health facilities safe, energy-efficient and resilient to future risks, including climate change (WHO, no date).

The Hospital Safety Index, developed by the WHO is a tool used by health authorities and multidisciplinary partners to gauge the probability that a health facility will continue to be safe and operational in emergency situations. The tool includes evaluation forms, a guide for evaluators, and a safety index calculator (WHO, no date).

WHO Health Emergency and Disaster Risk Management Framework: Launched at the Global Platform for Disaster Risk Reduction in May 2019, the WHO Health Emergency and Disaster Risk Management Framework is designed to reduce the health risks and consequences of emergencies and is vital to local, national and global health security and for building the resilience of communities, countries and health systems. Sound risk management is essential to safeguard the development and implementation of the Sustainable Development Goals (SDGs), including the pathway to universal health coverage (UHC), the Sendai Framework for Disaster Risk Reduction 2015-2030 (Sendai Framework), International Health Regulations (IHR) (2005), the Paris Agreement on Climate Change (Paris Agreement) and other related global, regional and national frameworks (WHO, 2019).

The WHO Health Emergency and Disaster Risk Management Framework provides a common language and a comprehensive approach that can be adapted and applied by all actors in health and other sectors who are working to reduce health risks and consequences of emergencies and disasters. The Framework also focuses on improving health outcomes and well-being for communities at risk in different contexts, including in fragile, low- and high-resource settings (WHO, 2019).

The WHO Health Emergency and Disaster Risk Management Framework emphasises assessing, communicating and reducing risks across the continuum of prevention, preparedness, readiness, response and recovery, and building the resilience of communities, countries and health systems (WHO, 2019).

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Coordination agency or organisation

World Health Organization (WHO) and UNICEF in collaboration with the United Nations Educational, Scientific and Cultural Organization (UNESCO).

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TL0208 / TECHNOLOGICAL / Construction / Structural Failure

Nuclear Plant Failure

Definition

Nuclear plant failure occurs when the accidental melting of the core of a nuclear reactor results in a complete or partial core collapse (adapted from USNRC, 1975).

Reference

USNRC, 1975. Reactor Safety Study: An Assessment of Accident Risks in US Commercial Nuclear Power Plants (Vol 88). United States Nuclear Regulatory Commission (USNRC). www.nrc.gov/docs/ML0706/ML070610293.pdf Accessed 29 January 2025

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Annotations

Synonyms

Nuclear meltdown, Nuclear shutdown.

Additional scientific description

Nuclear reactors are used to heat water to produce enormous amounts of low-carbon electricity and can be powered by a variety of different fuels. The fissioning of atoms in the chain reaction releases a large amount of energy as heat. The generated heat is removed from the reactor by a circulating fluid, typically water. This heat is then used to generate steam which drives turbines for electricity production (World Nuclear Association, 2020).

Electricity is essential for modern life, however, almost one billion people live without access to electricity. Global challenges such as climate change, pollution and environmental degradation require nations to generate electricity renewably (World Nuclear Association, no date). During the 20th century, the main energy sources for generating electricity were fossil fuels, hydroelectricity and since the 1950s, nuclear energy. Despite the growth and demand for renewable energy, fossil fuels remain the dominant source globally. Nuclear power is an environmentally friendly form of electricity generation. Although proponents of nuclear energy claim this is a renewable and safe form of energy, when nuclear plant failures do occur, they can have significant human, environmental, and socio-economic impacts (World Nuclear Association, no date).

In 2018, nuclear power generated 10.5% of the world's electricity (World Nuclear Association, 2020).

Nuclear reactors are a reliable source of energy and are capable of running for 24 hours a day for many months and possibly up to years without interruption, providing large amounts of clean electricity. Most nuclear reactors can operate for many years, over 60 years in some cases (World Nuclear Association, 2020).

Reactors derived from designs originally developed for propelling submarines and large naval ships generate about 85% of the world's nuclear electricity. The most common power reactor types use water, with more than 90% of the world's reactors being water-based (World Nuclear Association, no date).

The nuclear plant failures in Chernobyl and Fukushima are notable examples of major disasters.

Chernobyl, Ukraine (former Soviet Union) 1986: Chernobyl, is considered the world's worst nuclear disaster to date. A sudden power surge resulted in explosions and nearly complete destruction of the reactor. Fires broke out in the building which contributed to the extensive radioactive releases. The initial steam explosion and fire killed two people with a further 28 dying from radiation poisoning within three months. Massive amounts of radiation spread across the Soviet Union and Europe, and displaced 220,000 people as well as contributing to significant health,

environmental and socio-economic impacts (WHO, 2016; World Nuclear Association, 2019).

Fukushima, Japan 2011: The 2011 Great East Japan Earthquake and tsunami that struck Japan on 11 March 2011, destroyed four reactors at the Fukushima nuclear power plant due to the loss of cooling as a result of the tsunami. There were no deaths or serious injuries as a direct result of radioactivity.

Metrics and numerical limits

Design certification of reactors is the responsibility of national regulators. There is international collaboration among national regulators to varying degrees, and there are various sets of mechanical codes and standards related to quality and safety (World Nuclear Association, 2019).

Key relevant UN convention / multilateral treaty

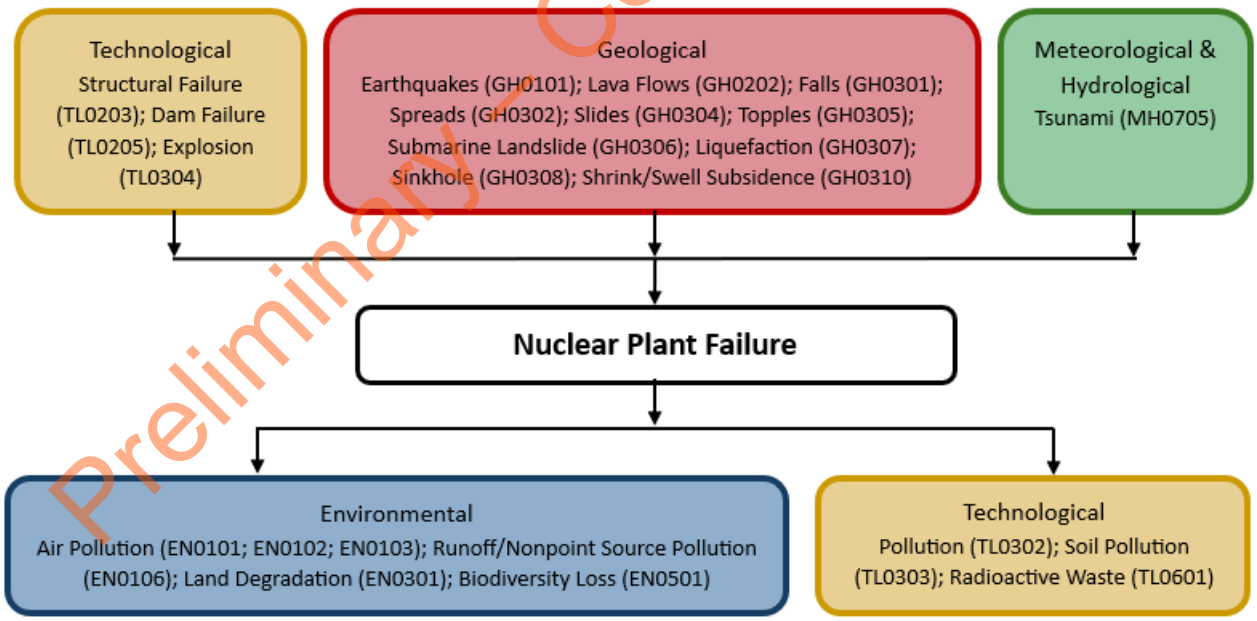
The Convention on Nuclear Safety, adopted 1994, aims to commit Contracting Parties operating land-based civil nuclear power plants to maintain a high level of safety by establishing fundamental safety principles to which States would subscribe. The Convention is based on the Parties' common interest to achieve higher levels of safety that will be developed and promoted through regular meetings (IAEA, 1994).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: An earthquake or a tsunami (external hazard) can lead to pipe ruptures or fires caused by damage to electrical equipment (internal hazards). Similarly, a heavy load falling (internal hazard) can cause internal flooding due to pipe breaks (another internal hazard) or a missile launch caused by mechanical equipment damage (internal hazard) (IAEA, 2017).

Impacts: failure of or damage to a nuclear power plant cause the release in the environment of radioactive material, with impacts on human health and the environment.

Multi-hazard Context: The figure below summarises common interactions between nuclear plant failure and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: No information Available

Risk Management: Despite recent nuclear disasters such as Chernobyl and the devastation that brought, there is very little risk of nuclear power plants releasing radioactive materials to nearby communities. There has been strong awareness of the potential hazard of both nuclear criticality and the release of radioactive materials from generating electricity through nuclear power, which has led to increased safety measures, an increase in well-trained reactor operators, thorough testing and maintenance, and policy and regulations put in place by

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organizations such as the Nuclear Regulatory Commission (USNRC, 2011; World Nuclear Association, 2019). The design and operation of nuclear power plants to date aims to minimise the likelihood of accidents and avoid major human consequences through the implementation of nuclear safety measures and risk-informed decision-making (USNRC, 2011).

The International Atomic Energy Agency (IAEA) reports that nuclear power plants are equipped with multiple safety systems able to deal with a wide range of abnormal operating conditions. They also have well-proven emergency operating procedures that help operators achieve a stable and safe end state. However, the most severe circumstances can result in damage to the nuclear fuel and the containment structures, possibly leading to a release of radioactivity into the environment. Yet even in these events the consequences can still be mitigated using available and, in some cases, dedicated plant equipment (IAEA, no date).

To protect the public and the environment from the consequences of a nuclear power plant accident, each plant operator establishes a severe accident management programme, which is kept under constant review and development. The main objective of the guidelines used to design such programmes is to utilise any available equipment at the nuclear power plant to terminate core damage, maintain containment integrity and minimise the release of radioactivity from the site (IAEA, no date).

The severe accident management guidelines vary according to plant design, local regulations and site characteristics. The IAEA has developed a toolkit to help operators develop their own guidelines and offers its Member States modular training programmes (IAEA, no date).

Although they are unlikely to be needed, severe accident management programmes are a critical part of the Defence in Depth concept, which is a hierarchical deployment of different levels of equipment and procedures in a graded approach to protect against a wide variety of incidents, accidents, equipment failures, human errors and events initiated outside the plant. In general, severe accident management programmes are designed to: evaluate generically the capability of existing plants to tolerate a severe accident; identify events that can lead to severe accidents and formulate preventive and mitigation strategies; and identify short-term and long-term measures for handling severe accidents (IAEA, no date).

The IAEA provides extensive materials on nuclear power plant safety systems which are designed to mitigate a range of abnormal operating conditions. In the unlikely case of a severe accident, plant operators use guidelines developed specifically for the purpose. The IAEA has a toolkit to help operators develop these guidelines and offers training to its Member States (IAEA, no date).

In addition, the IAEA organises the International Conference on Radiation Safety: Improving Radiation Protection. In 2020 it was held virtually, from 9 to 20 November. The Conference was organised in cooperation with the European Commission, the Food and Agriculture Organization of the United Nations, the International Labour Organization, the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development, the Pan American Health Organization, the United Nations Environment Programme and the World Health Organization (IAEA, 2020).

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Coordinating agency or organisation

Not identified.

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TL0209 / TECHNOLOGICAL / Construction/Structural Failure

Power Outage/ or Blackout

Definition

In the electric power domain, especially in power transmission and distribution, a power outage usually refers to a partial or total loss of power supply to some end user (e.g., population, enterprises, critical systems). Triggering factors may include accidents, equipment breakdowns, failure of control mechanisms, targeted attacks (physical or cyber), organisational errors, and natural hazards (adapted from Pescaroli et al., 2017; UK Cabinet Office, 2017; EIS Council, 2019; FEMA, 2018).

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Annotations

Synonyms

Electricity failure, Electricity disruption, Power cut, Power loss, Brownout, Power failure, Electricity outage,

Additional scientific description

Power outages can manifest in various forms, including transient faults, brownouts, and blackouts. They may initiate from both the supply and demand side. In some cases, power outages also materialise as the result of a situational response, such as in order to prevent worse consequences (e.g., rolling blackouts).

Event severity of power outages may exceed the ordinary by far; for instance, the Electric Infrastructure Security Council defines a Black Sky Hazard as “a catastrophic event that severely disrupts the normal functioning of our critical infrastructures in multiple regions for long durations” (EIS Council, 2019). The process of full restoration of the electricity network after the total or partial shutdown of the grid is sometimes termed as a black start (UK Cabinet Office, 2023).

Terminology and definitions may vary, even significantly, across operational contexts and agencies.

Metrics and numeric limits

Metrics are in place to capture the many facets of a power outage. Some of these metrics are derived from standards such as IEEE 1366-2012 (IEEE, 2012).

- Duration/frequency/occurrence time. For electric power utilities, commonly used reliability indicators include the System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI). In power outage analysis and reporting, it is common to refer to short- to long-duration events as a function of the specific legislative and operational context. For instance, the US Department of Homeland Security (2017) refers to a "long-term (+72 hours) interruption", while in general customer interruptions are considered as power outages even if much briefer. Important figures are those related to the occurrence times of the failure event chains.
- Magnitude and size. Typical indicators assess the affected parts and quotas of the grid, the estimated electricity not provided, or the geographic extent of the event. Power outages are often described as local, regional, national, cross-national, up to global. However, geography-based reporting may depend on jurisdictions and generally it is not possible to find an official definition on the size of blackouts (Galbusera and Giannopoulos, 2018).
- Number of users affected. Figures typically considered are the number of people or households affected, or similar indicators for industries and businesses, sometimes accompanied by spatio-temporal details (Galbusera and Giannopoulos, 2018).
- Economic indices. Indices in use to evaluate supply interruption-related costs include, the Interruption Energy Assessment Rate (IEAR), Value of Lost Load (VOLL), and Willingness to Pay (WTP) (e.g., €/kWh). A comprehensive impact quantification should account for both direct and indirect costs (Galbusera and Giannopoulos, 2018).
- The System Average Interruption Duration Index (SAIDI) is a metric used in the electric power industry to measure the reliability of a utility's power system. It represents the average total duration of power outages experienced by a customer in a given period, typically a year. SAIDI is calculated by summing the total outage duration for all customers served and dividing by the total number of customers. A lower SAIDI value indicates a more reliable power system. (World Bank, no date a)
- The System Average Interruption Frequency Index (SAIFI) is a metric used by electric power utilities to measure the average number of power interruptions experienced by a customer over a given time period, typically a year. It's calculated by dividing the total number of customer interruptions by the total number of customers served. SAIFI is measured in units of interruptions per customer. (World Bank, no date b)

Key relevant UN convention / multilateral treaty

The Sendai Framework for Disaster Risk Reduction 2015-2030 includes disaster risk reduction objectives related to critical infrastructures (UNISDR, 2015). Disaster reduction policies on power outages stand at the crossway of commercial and market-regulatory treaties, development strategies, and national/cross national security agreements in the field of critical infra- structure protection.

At the EU level, relevant policy documents include:

- Council Directive 2008/114/EC (European Parliament Think Tank, 2021);
- Directive 2009/72/EC (European Commission, 2009);
- Directive (EU) 2019/944 (European Commission, 2019)
- Directive (EU) 2022/2557 on the resilience of critical entities [Directive (EU) 2022/2557 of the European Parliament and of the Council of 14 December 2022 on the resilience of critical entities] (European Commission, 2022).

Multi-country agreements in place include, for instance, the 2015 International Energy Charter (Energy Charter, 2015).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Power outages are associated with cascading and systemic risks rooted at the intersection between physical, societal, functional and organisational dynamics (Pescaroli and Alexander, 2016). Triggering events include failure of operation, failure of equipment or material damage, human errors, ageing infrastructure, and damage caused by natural hazards on equipment, facilities and lines (Amin, 2002; Little, 2002; Petermann et al., 2011;

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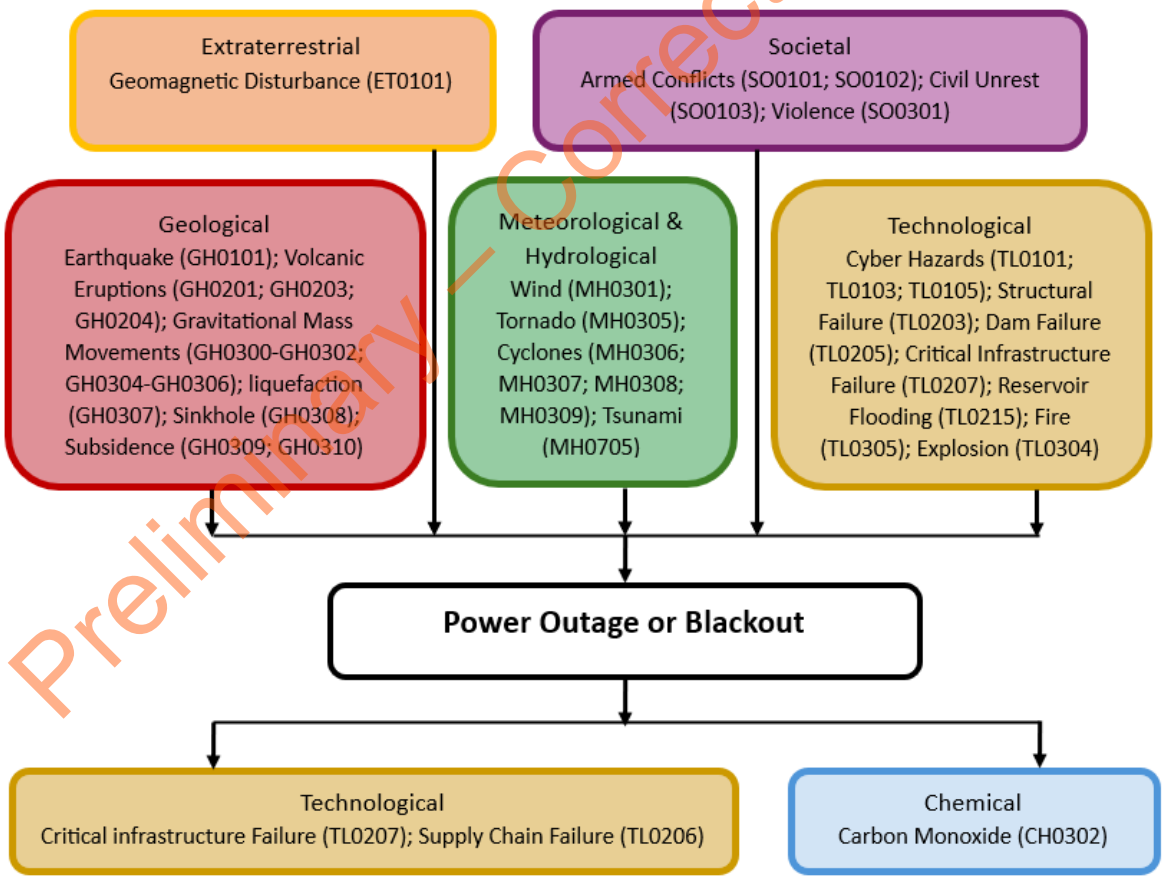
Karagiannis et al., 2017). Directly and indirectly targeted malicious acts include cyberattacks, terrorist acts, or electromagnetic pulse attacks (Amin, 2002; Linkov et al., 2013).

Impacts: The impact of power outages can have cascading effects on healthcare systems, communication networks, and water supply systems. These can be amplified if the outage happens in concurrency with climate-related extreme events (e.g., cold waves, heat waves) (Klinger et al., 2014). Since the early 2000s, larger impacts of power outages have been associated with growing and varying demand, network size and complexity, as well as market deregulation (Helbing et al., 2006). Electric power is indispensable in modern society, influencing work, healthcare, leisure, economy, and livelihood. Critical social services such as emergency response, law enforcement, transportation, and communication systems heavily rely on uninterrupted electricity. Extended power outages can greatly impair their functionality, posing risks to public safety and hindering emergency response efforts (Rouhana et al., 2025).

Petermann et al. (2011) illustrated that power outages can heavily disrupt societal and economic functions both directly (due to the lack of energy they rely on) and indirectly (e.g., through interdependencies). According to Pescaroli et al. (2017), the effects of power outages are associated with direct threats to life (e.g., impacts on the health sector, water shortages, or disruption of heating and cooling); indirect threats to life (e.g., increased need of the vulnerable population, loss of cash flow); and challenges for operational capacities (e.g., loss of efficiency of emergency services).

During power outages, people may turn to alternative energy sources during blackouts - e.g. stoves and burners used inside, which may cause carbon monoxide poisoning (CH0302).

Multi-hazard Context: The figure below summarises common interactions between power outages or blackouts and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: Not Applicable

Risk Management: Risk management strategies include national and international risk assessments, development of policies and practices for continuity management, training and exercises for complex scenarios involving multiple

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interdependent failures, assessment of new technologies (e.g., microgrids, cashless transactions), and the improvement of crisis communication before, during and after power outage events (FEMA, 2018).

Khediri et al. (2024) proposed a novel Early Warning System for predicting blackouts in smart grids. This system is based on deep learning models, specifically Convolutional Neural Networks (CNN) and Deep Self-Organizing Maps (DSOM), designed to analyse data from various sources, including power demand, generation, transmission, distribution, and weather forecasts. The system's performance was evaluated using a dataset composed of time windows and labels indicating whether a blackout occurred within the respective time frame. It achieved an accuracy of 98.71% and a precision of 98.65% in predicting blackouts. These results suggest that the Early Warning System is a promising tool for enhancing the resilience and reliability of power grids while mitigating the impacts of blackouts on communities and businesses (Khediri et al., 2024).

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Coordinating agency or organisation

Not identified.

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TL0210 / TECHNOLOGICAL / Construction/Structural Failure

Water Supply Failure

Definition

Water supply failure is the physical shortage or scarcity in access of water supply due to the failure of institutions to ensure a regular supply or due to a lack of adequate infrastructure (adapted from UN-Water, no date).

Alternative definition: Water supply systems are networks whose edges and nodes are pressure pipes and either pipe junctions, water sources or end-users. Water supply systems are designed to protect the customer from natural biological contamination, and the same systems have potential efficacy against deliberate biological and chemical contamination (adapted from Franchin and Cavalieri, 2013; and Jain et al., 2014).

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Annotations

Synonyms

Water network failure, Potable water failure, Drinking water shortage.

Additional scientific description

Water is essential for socio-economic development, energy and food production, healthy ecosystems and human survival. Access to safe drinking water is a major global health concern and water is also considered at the core of adaptation to climate change, providing the crucial link between society and the environment.

As the global population rises, there is a need to balance competing demands on water resources to provide basic necessities for operation and survival. In order to keep up with demand, water supply systems require periodic inspections, maintenance and repairs. Inspections allow for early detection of potential damage, with planning for

repair to prevent negative and ongoing consequences associated with the lack of water supply (Pietrucha-Urbanik and Tchórzewska-Cieślak, 2018). Recent practice to reduce the number of emergency failures has been the implementation of preventative renewal. This identifies the elements within the water supply systems that are most vulnerable to failure and ensures that they are replaced, thereby reducing the probability of failure (Pietrucha-Urbanik and Tchórzewska-Cieślak, 2018). This has largely been applied to ageing infrastructure. Actions taken to reduce the number of water supply system failures include but are not limited to: technical renewal of pipelines (renovations, maintenance and diagnostics); replacement of pipes and fittings; improvements in detecting places of leaks; network pressure limitation to the lowest permissible value; and proper operation, design and execution of water supply systems.

Metrics and numeric limits

While significant progress has been made towards improving water supply infrastructure and achieving access to basic water, sanitation and hygiene, gaps remain in the quality of services provided. A recent report concluded that 1.8 billion people have gained access to basic drinking water services since 2000, but there remain vast inequalities in the accessibility, availability and quality of these services and more than 2 billion people around the world do not have safely managed drinking water (UN-Water, no date a).

Key relevant UN convention / multilateral treaty

The United Nations Sustainable Development Goals (2015), specifically with regard to achieving universal and equitable access to safe and affordable drinking water for all (Goal 6: Ensure availability and sustainable management of water and sanitation for all) (United Nations, 2015).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: A water supply system loss of safety may result from: failure of its individual subsystem or elements such as water intakes, pumping stations, the water distribution network or its utilities; failure of other technical systems such as sewerage, energy, water structures; extreme natural hazards such as floods and droughts; poor organisational structures; and from incidental pollution of water sources (Pietrucha-Urbanik and Tchórzewska-Cieślak, 2018).

Impacts: A water supply system failure generally results in a decreased amount of water supplied with inadequate parameters such as low pressure which could lead to water scarcity. Public water system bodies have the responsibility of maintaining physical and human infrastructure to supply water and are often bound by regulations. However, water use has been increasing globally at more than twice the rate of population growth over the past century. Some regions are reaching the limit at which services can be sustainably delivered. In the latter half of the twentieth century, there was an increase in major accidents and disasters relating to the functioning of public water supply systems in rural, urban and industrial areas (Pietrucha-Urbanik, 2015).

Water supply system failure can lead to water contamination and water scarcity, which may result in the outbreak of waterborne diseases such as cholera and diarrhoea. Additionally, in such situations, the search for alternative water sources by people can cause further hazards, such as groundwater depletion. (UNESCO, 2023)

Multi-hazard Context: The figure below summarises common interactions between water supply failure and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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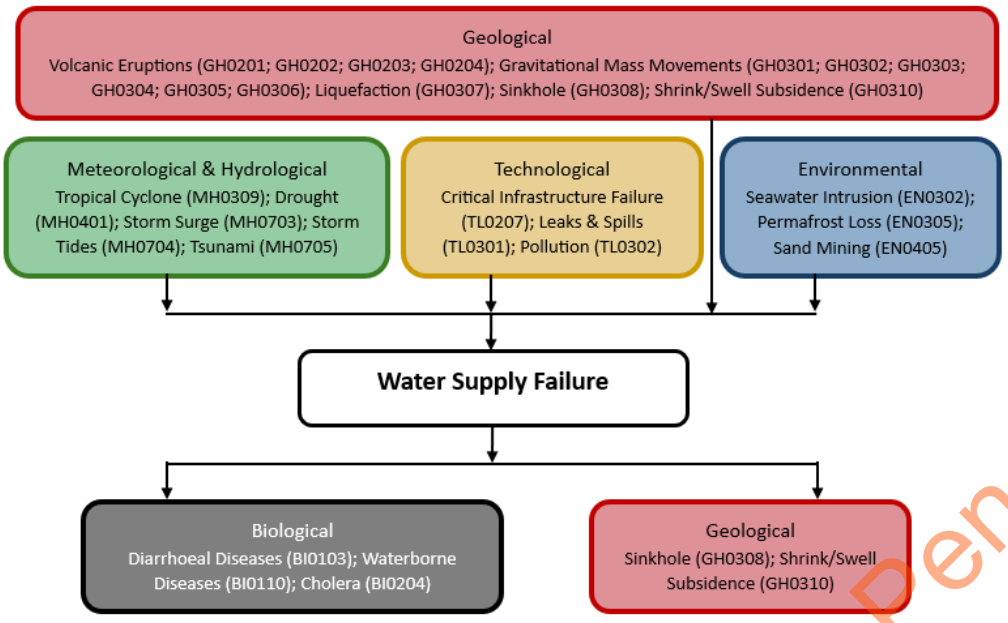

Monitoring: The United Nations (UN) seeks to support countries in monitoring water and sanitation-related issues within the framework of the 2030 Agenda for Sustainable Development and in compiling country data to report on global progress toward Sustainable Development Goal 6 (SGD6). The aim of this initiative is to increase the availability of high-quality data to inform evidence-based policymaking, regulations and planning investments at all levels.

Risk Management: In recent decades, analyses and assessments of water system failures have been conducted in many countries, concluding that assessments have been used to improve programming, design, implementation and operation, and to inform and/or amend technical regulations, design standards, guidelines and instructions for the performance and acceptance of facilities of water supply systems (UN-Water, no date a).

Integrated water resources management, which has been accepted internationally, provides a broad framework for governments to align water use patterns with the needs and demands of different users (UN-Water, 2008).

In addition to Integrated Water Resources Management, a number of regulations and standards have been developed to address water supply security and safety, particularly from the World Health Organization with regard to the applications of water safety plans, some of which include:

- Water sanitation hygiene: Global water supply and sanitation assessment 2000 report (WHO, 2000a).
- Operation and maintenance of rural water supply and sanitation systems A training package for managers and planners (WHO, 2000b).
- Global costs of attaining the Millennium Development Goal for water supply and sanitation (WHO, 2008).
- Vision 2030: The resilience of water supply and sanitation in the face of climate change Summary and policy implications (WHO, 2009).
- Guidance on water supply and sanitation in extreme weather events (WHO Regional Office for Europe, 2012).

UN-Water has developed a global data portal 'The SDG 6 Data Portal' which brings together all the UN's water and sanitation information to show the global status of Indicator 6.4.1: Change in water-use efficiency over time. The objective of the portal is to: track overall progress towards SDG6 at global, regional and national levels; enable assessment and analysis of the state of water resources and linkages to other sectors; raise awareness of water and sanitation issues to help catalyse action; and encourage and improve SDG6 monitoring and reporting at all levels (UN-Water, no date b).

A water supply vulnerability early warning system predicts potential weaknesses within water supply systems, enabling decision-makers to take timely and appropriate actions. These systems analyse critical variables such as precipitation, runoff, and hydrological changes, issuing alerts before thresholds are reached to mitigate risks. Such early warning mechanisms can support long-term water supply management and inform policy decisions effectively (Robinson et al., 2020).

Preliminary – Corrections Pending

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Coordination agency or organisation

World Health Organization (WHO) and United Nations International Children's Emergency Fund (UNICEF) in collaboration with United Nations UN-Water.

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TL0211 / TECHNOLOGICAL / Infrastructure Failure

Emergency Telecommunications Failure

Definition

Emergency telecommunications failure is an umbrella term for telecommunications of an 'extraordinary nature' under abnormal and potentially adverse network conditions (ITU, 2007).

Reference

ITU, 2007. Y.2172: Service restoration priority levels in Next Generation Networks. International Telecommunication Union (ITU). www.itu.int/rec/T-REC-Y.2172-200706-I/en Accessed 26 January 2025.

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Annotations

Synonyms

Emergency communication systems, Communications capability, Emergency telecommunications, Network-enabled capability, Emergency services, Emergency network failure.

Additional scientific description

Emergency telecommunications are critical when a disaster occurs, to enable emergency and disaster response teams, government ministries, departments and agencies, as well as humanitarian agencies to coordinate and deliver disaster response and recovery efforts. Emergency telecommunications failure is closely linked to service restoration. Service restoration is described as a set of automated or manual methods, invoked after a network failure, to enhance the ability of successful communications reroute and completion around the failed network element(s) (ITU, 2014).

All forms of communications traffic are expected to be carried by next-generation networks – control plane traffic (e.g., routing and signalling messages), emergency telecommunications, real-time voice and video services, data services, virtual private network (VPN) services, as well as traditional 'Best effort' traffic. In such an environment, it is important to assign priority classifications and establish rules for service restoration such that critical services (e.g., control plane traffic and emergency telecommunications) are recognised and restored over other services in case of network overloads or failures. As service flows can be expected to traverse multiple network domains, priority classification is an important step in the development of the necessary signalling protocol extensions as well as of the mechanisms for enabling preferential restoration of critical services (ITU, 2014).

The requirements for disaster communication in terms of reliability, ruggedness and resilience also differ in different phases of a disaster. The broad scope of disaster management from a communication perspective needs to be handled as regards the type of communication technologies and their utilization in the various phases of the disaster (ITU, 2014).

Metrics and numeric limits

The ITU is currently developing global guidelines for countries to develop National Emergency Telecommunications Plans (NETS) to be used for early warning and in times of emergency (GMSA, 2021). The framework seeks to address a country's exposure to natural hazards and disasters prior to developing emergency data and communication systems (ITU, 2019).

Key relevant UN convention / multilateral treaty

The Tampere Convention on the Provision of Telecommunication Resources for Disaster Mitigation and Relief Operations was established in 2005. This international treaty allows countries to remove regulatory issues to immediately provide emergency telecommunications where a disaster has occurred (United Nations Treaty Collection, 1998).

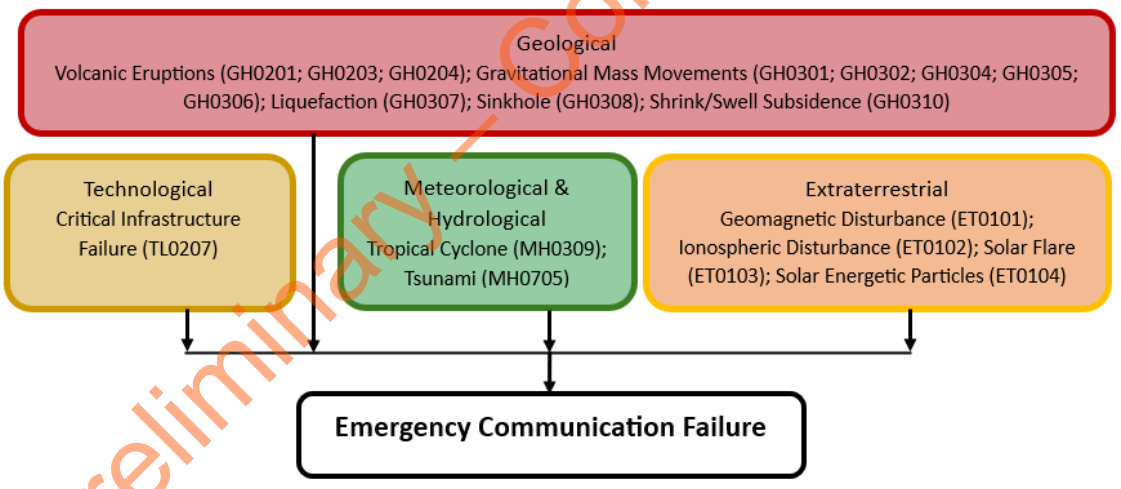
Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Natural hazards can destroy telecommunications infrastructure and cause severe network disruptions. Electrical power is essential for these emergency communication systems to operate and power outages are directly linked to the drivers of this hazard (Townsend and Moss, 2005; Chang et al., 2007). In addition, human-caused hazards, such as sabotage, vandalism and war, impact emergency telecommunications. Natural hazards impact emergency telecommunication. During and after an earthquake, emergency communications are crucial. Reliable communication is vital for disseminating information, coordinating rescue efforts, and allowing people to stay informed and connect with loved ones. In the immediate aftermath, traditional phone calls may be unreliable, so text messages, social media, and battery-operated radios become important communication tools (US Department of Homeland Security, 2024; PAHO, 2009). Solar geomagnetic storms generate X-rays and solar radio bursts accelerate solar particles to relativistic velocities, causing major perturbations to the solar wind, and can cause detrimental effects to the electricity grid, satellites, avionics, air passengers, signals from satellite navigation systems, mobile telephones and more. (National Research Council, 2008; Royal Academy of Engineering, 2013)

Impacts: Emergency telecommunications failure can lead to the malfunction of early warning systems, increasing the potential for secondary damages. It also diminishes disaster response capabilities by causing delays or reducing the efficiency of emergency response operations. Furthermore, due to its interdependency with power and ICT systems, telecommunications infrastructure can become a target for cyber-attacks, creating additional vulnerabilities in the system (CISA, 2023).

Failure in emergency communications will have more impact in the context of other hazards, for example, wildfires are the most frequent type of emergency, particularly affecting transmission network circuits (Salema & Caldeirinha, 2024). Issues around emergency telecommunications failure increase the risk of physical damage and financial losses, where quick service restoration, to enhancing disaster response capabilities for improving emergency connectivity are vital.

Multi-hazard Context: The figure below summarises common interactions between emergency communication failure and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: Emergency telecommunications failures exacerbate disaster risks by hindering communication and coordination among responders, potentially leading to delayed or ineffective emergency response and increased physical and financial damage. Quick service restoration is crucial for enhancing disaster response capabilities, as it enables timely communication, information sharing, and coordinated actions to mitigate damage and aid affected populations (OECD, 2025).

Risk Management: The ITU's NETS framework can be used across all stages of the disaster management cycle and provides guidelines for a country to establish robust Information and Communication Technologies (ICT) systems before, during and after a disaster (ITU, 2019).

In large-scale disaster situations, emergency telecommunication failures are likely due to network overload or interdependencies with power systems. To address these risks, it is crucial to enhance the resilience of communication systems by implementing measures such as network traffic and system performance monitoring. Additionally, risks can

Preliminary – Corrections Pending

be mitigated through the establishment of backup communication systems, securing alternative communication pathways, and pre-planning the personnel and resources needed to ensure uninterrupted operations.

Mobile technology serves as a critical tool in mitigating emergency telecommunications failure, enabling effective communication across all phases of disaster management, including preparedness, resilience-building, response, and recovery. It ensures access to vital information and plays a particularly significant role in the dissemination and communication of early warnings (GSMA, 2023).

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Coordinating agency or organisation

International Telecommunication Union (ITU), in partnership with World Food Programme (WFP), United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA) and United Nations High Commissioner for Refugees (UNHCR).

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TL0212 / TECHNOLOGICAL / Construction/Structural Failure

Radio and Other Telecommunication Failures

Definition

Radio and other telecommunication failures occur when there is an internal or external interruption of communications by either party that results in difficulty transporting a message as it was intended (adapted from Dainty et al., 2007).

Reference

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Annotations

Synonyms

Communication breakdown, Communication system failure.

Additional scientific description

Radio and communication technology is integrated into everyday life and has significantly advanced in recent decades. Communication channels such as radio, cellular networks, and satellites aim to broadcast or convey information and warnings to populations. In a disaster response event, the goal of any communication system is to maximise the number of people who act on and take appropriate and timely actions to protect property and ensure life safety (Khaled & Mcheick, 2019; ITU, 2019).

Efficient and effective communication linkages are critical prior to, during and following a disaster event, particularly among emergency personnel to assist with disaster response and recovery. However, failure of communication systems, whether complete or partial such as radio or satellite systems has caused inefficiency and delays in emergency relief efforts and response, which leads in turn to loss of life and preventable injuries. Failure of communication systems can cause catastrophic damage to human life and economic activities as people are unable to communicate with each other in a timely manner and with a good quality of service (Khaled & Mcheick, 2019).

A notable example of radio and communications failure was caused by the 2004 Indian Ocean earthquake and tsunami: A magnitude 9.0 earthquake struck the west coast of Sumatra, Indonesia, generating tsunami waves with maximum heights ranging from 2 to 30 m, inundating the coastal areas of many surrounding countries. Although this event was the first global natural disaster where practitioners and the public mediated their experience of it through the internet, communication technology was not used to its fullest extent during the immediate response, which resulted in a lower delivery of humanitarian aid. The main reasons for the communication failure were the destruction of technology infrastructure, accumulated debris, and extensive flooding that affected the power systems and cabins that contained the base transceiver station (BTS) equipment. There were also other telecommunications limitations such as limited network coverage, lack of early warning systems, and a lack of rescue equipment (Khaled & Mcheick, 2019).

Key reasons for communication systems failure include damage and/or destruction of communication system

components; damage and/or disruption in supporting network infrastructure; and disruption due to congestion.

Damage and/or destruction of communication system components is considered the most common and well-documented cause of telecommunications failures in recent disasters. Because of the time and funding needed to repair and replace systems, disruption caused by physical damage tends to be more severe and time-consuming to restore as it may require maintenance or replacement of complex hardware, particularly essential components such as cell towers or cables. The fragility of communication systems is due to the lack of a high degree of redundancy (Townsend and Moss, 2005).

Communication outages caused by damage and/or disruption in supporting network infrastructure tend to be far more widespread and damaging during response and recovery efforts. Some communication systems are reliant on many other local and regional technical systems to ensure effective operation. Supporting infrastructure often lacks resiliency to physical damage (Townsend and Moss, 2005).

Disruption due to congestion is another type of major communication failure during disaster, and is a direct result of network congestion or overload, and results in blocked calls and messages unsent. Historically, disasters are one of the most intense generators of communications traffic, and the resulting surge of demand can clog even the most well-managed networks.

However, communication can be restored relatively rapidly (Khaled & Mcheick, 2019).

Lessons identified from previous disaster events, conclude that radio and satellite-based communications were most effective, while conventional communications outlets (i.e. wireless phones and landlines) were either damaged or overwhelmed in many disaster events hindering the efficient and timely transfer of information (Khaled & Mcheick, 2019).

Metrics and numeric limits

The ITU is currently developing global guidelines for countries to develop National Emergency Telecommunications Plans (NETS) to be used for early warning and in times of emergency (GMSA, 2021). The framework seeks to address a country's exposure to natural hazards and disasters prior to developing emergency data and communication systems (ITU, 2019).

Key relevant UN convention / multilateral treaty

Sustainable Development Goals (SDGs) (UNDESA, 2021).

The Tampere Convention on the Provision of Telecommunication Resources for Disaster Mitigation and Relief Operations was established in 2005. This international treaty allows countries to remove regulatory issues to immediately provide emergency telecommunications where a disaster has occurred (United Nations Treaty Collection, 1998).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Natural hazards can destroy telecommunications infrastructure and cause severe network disruptions. Electrical power is essential for these emergency communication systems to operate and power outages are directly linked to the drivers of this hazard (Townsend & Moss, 2005; Chang et al., 2007).

Impacts: Radio and other telecommunication networks should be able to step in if emergency telecommunications failure occurs as it can lead to the malfunction of early warning systems, increasing the potential for secondary damages. It also diminishes disaster response capabilities by causing delays or reducing the efficiency of emergency response operations. Furthermore, due to its interdependency with power and ICT systems, telecommunications infrastructure can become a target for cyber-attacks, creating additional vulnerabilities in the system (CISA, 2023).

Failure in radio and other telecommunication networks will have more impact in the context of other hazards, for example, wildfires are the most frequent type of emergencies, particularly affecting transmission network circuits (Salema & Caldeirinha, 2024). Issues around emergency telecommunications failure increase the risk of physical damage and financial losses, where quick service restoration, to enhance disaster response capabilities for improving emergency connectivity are vital.

Multi-hazard Context: The figure below summarises common interactions between radio and other telecommunication failures and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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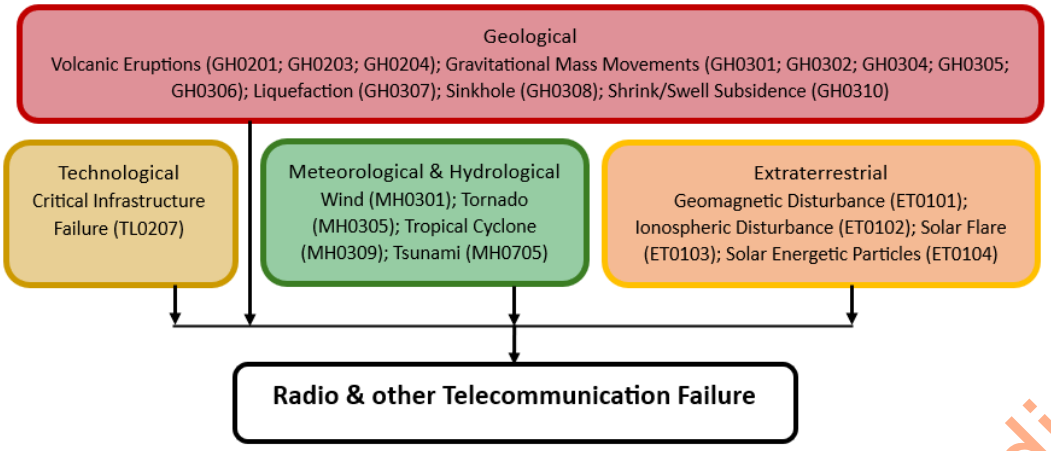

Monitoring: Emergency telecommunications failures exacerbate disaster risks by hindering communication and coordination among responders, potentially leading to delayed or ineffective emergency responses, and increased physical and financial damage. Quick service restoration is crucial for enhancing disaster response capabilities, as it enables timely communication, information sharing, and coordinated actions to mitigate damage and aid affected populations (OECD, 2025).

Risk management: Developing and implementing common technical characteristics and guidelines for radio communication systems for early warning and disaster response and relief, would promote a common technical basis in planning for and responding effectively to an emergency. A guide to Radio Communications Standards for Emergency Responders was developed and prepared under the United Nations Development Program and the European Commission Humanitarian Office through the Disaster Preparedness Programme. The aim of the manual is to provide a standard of operation and a guide for training message handling techniques and net procedures for Radio Emergency Service operators for national and local radio networks (UNDP, 2010). In 2017, the United Nations Children Fund (UNICEF) developed an Emergency Telecommunications Handbook which presents a set of guidelines and detailed instructions to support teams facilitating and delivery of effective emergency telecommunications in the field. The handbook captures the nature of integration of various telecommunication systems (UNICEF, 2017).

In addition, the International Telecommunication Union has developed numerous resources including:

- Radio Regulations Navigation Tool (regulations that govern the global use of the radio-frequency spectrum and satellite orbits) (ITU, no date).
- Space Networks Systems Database of the Radiocommunication Bureau of the International Telecommunication Union. The database contains AP4 data of geostationary satellite filings, non-geostationary satellite filings and earth station filings (ITU, no date).
- Definitions of world telecommunication/ICT Indicators (ITU, no date).

Radio-based early warning systems (EWS) are among the oldest and most reliable communication technologies, having been extensively tested in various disaster scenarios. Radio has the unique advantage of reaching large populations in areas where infrastructure has been severely damaged, making it a cost-effective means of communication. During the immediate response phase of various natural disasters, radio has been instrumental in delivering critical messages, information, and advice to affected communities, often in collaboration with diverse stakeholders. One of the key strengths of radio is its ability to reach individuals in resource-limited settings, where other forms of communication may not be feasible due to limited infrastructure or high costs. In situations where electricity is unavailable, and thus mobile phones, televisions, or other media channels cannot be used, solar or wind-powered radios offer a sustainable and easily deployable solution, ensuring that vital early warnings continue to reach communities without requiring advanced technology or significant resources. This makes radio an invaluable tool in ensuring communication continuity, even when other communication infrastructures fail (Hugelius K. et a.l, 2019).

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Coordination agency or organisation

International Telecommunication Union.

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TL0213 / TECHNOLOGICAL / Construction/Structural Failure

Tunnel Failure

Definition

Tunnels are artificial confined underground structures, which are used for different purposes; where, for example, collapses, fires, explosions and water ingress may damage tunnel facilities and cause injuries and human casualties, resulting in severe social harm (Adapted from Zafirovski et al., 2018 and Chien and Chao, 2021).

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Annotations

Synonyms

Tunnel collapse (including tunnels, caverns, tunnelling incident, shafts and associated underground structures howsoever constructed and including the renovation of existing underground structures), underground failure, subsidence events, underpass failure, passage failure.

Additional scientific description

Tunnels are civil engineering structures that are constructed for the purpose of securing space in the ground. They are categorized based on their intended use, such as road tunnels, railway tunnels, storage and waterway tunnels. Additionally, tunnels can be further classified by location conditions into mountain tunnels and city tunnels (JICA, 2018). Tunnels generally refer to online structures in which a predetermined cross-section is continuous in the longitudinal direction. According to the OECD definition, a tunnel is a cavity which is located below the ground surface and is used in some way and made into a prescribed geometry and has a cross-section of two square meters or more (OECD, 2001).

Tunnels are civil engineering structures designed to secure underground space. Their uses include transportation (road, rail, metro), hydraulic purposes (water, stormwater and wastewater), utility corridors (electrical, communications, gas), underground facilities (warehouses, hangars), renewable energy including hydropower, energy storage and nuclear waste disposal and scientific research applications.

Tunnels can be categorized by their primary function:

- Transportation tunnels (railway, roadway, pedestrian, metro)
- Hydraulic conveyance tunnels (water and wastewater, flood mitigation,)
- Utility distribution tunnels (electrical, telecommunications, gas, heating)
- Industrial and military tunnels (aircraft hangars, submarine shelters, underground storage facilities, industrial plants)
- Tunnels used as part of hydropower installations and energy storage
- Scientific and experimental underground spaces (Zafirovski et al., 2019)

Tunnels differ in structural form primarily influenced by functional requirements, but also in relation to the ground conditions (geotechnical factors) and the method of construction to provide ground support (lining). Lining materials include rock anchors, sprayed concrete, pre-cast segmental linings, cast-in-place concrete, and prefabricated steel or cast-iron segments.

Tunnel failure refers to the inability of a tunnel or its components to perform its function as specified by its design and construction requirements. This definition includes total collapses, partial collapses, excessive deformations, water ingress, fire, explosion, gas incursion, ground instability due to mining activities, tunnelling near weak surface structures, and sometimes excessive ground settlement leading to damage to overlying structures. Tunnel failures may occur during construction, during operational life, or due to external environmental impacts such as flooding, seismic activity, or fire.

Despite the severe consequences when failures do occur, the number of tunnel incidents worldwide remains exceptionally low in proportion to the number of tunnels constructed and operated daily. The underground environment, when properly engineered and managed, offers resilience and safety benefitting from the natural confinement provided by surrounding geology and the protection it offers against surface-level risks such as wind and extreme temperatures. Tunnel structures generally exhibit superior seismic performance compared to above-ground structures (Huan S et al 2024); however, they can still sustain catastrophic damage during powerful earthquakes particularly when crossing active fault zones (Zhang et al., 2023)

Operational risks include ageing infrastructure, changed use, operational error, corrosion of reinforcements, overloading, or inadequate maintenance. The most severe, but relatively rare incidents involve structural collapses, sometimes trapping workers or passengers inside. In rescue scenarios, further collapses or damaged ventilation systems can pose life-threatening conditions. Similarly, the 1999 Mont Blanc Tunnel fire, which killed 39 people, highlighted the fire risk from vehicle engines, emergency evacuation routes, advanced smoke extraction systems and emergency ventilation. A comparative analysis of the Mont Blanc, Tauern, and Gotthard tunnel fires (Voeltzel & Dix, 2004) emphasized the importance of risks from the users of the tunnel, rapid fire detection, inadequate emergency regulation, effective operator response, and timely self-evacuation by users.

Metrics and numeric limits

No standard reporting currently exists on tunnel failures, accidents or collapses. Various reports exist including information on previous large tunnel fires (OECD, 2001 and Chien & Chao, 2021) and studies on tunnel collapse failures such as Spyridis & Proske (2021)

Key relevant UN convention / multilateral treaty

The United Nations Committee of Experts for the Transport of Dangerous Goods enhances global transport efficiency through a harmonized regulatory framework (ECE Inland Transport Committee ADR 2024, Volume I and Volume II)

Amendments to and Implementation of the 1968 Conventions on Road Traffic and on Road Signs and Signals and the 1971 European Agreements Supplementing them: Safety in Tunnel (UNESC 2003)

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Tunnel failures are much more likely to occur during construction than during operational phases. When they occur, it may be from a combination of factors including workmanship, design, construction sequencing, intrinsic geotechnical (ground) conditions due to unanticipated rock behaviour, high ground stresses, karstic voids, and unanticipated water ingress. Failure to manage the design and construction process in view of the ground conditions whether from insufficient ground support, or inadequate ground treatment or drainage or operation of specialised plant and equipment, during the operation of a tunnel, there are potential fire and explosion risks with vehicle fires, hazardous material spills, gas explosions, electrical system failures (Chien & Chao, 2021). Driver error or communication breakdown are also among human hazard drivers.

Some of the most common tunnelling hazards include tunnel stability issues, such as rock falls and rock bursts, and changing ground conditions, including variation in strata and stress fluctuations. Furthermore, since it has limited space and access challenges, it is vulnerable to air contamination, oxygen depletion and risks of fire or explosion (Safe work Australia, no date). While the tunnel is in service, the open ends of a tunnel are susceptible to natural and meteorological disasters such as rock falls, avalanches, debris flows and earthquakes (JICA, 2018).

Impacts: The primary threat in the event of a tunnel collapse is the direct crushing impact caused by falling concrete, rocks, structural elements and flood water. If individuals become trapped under debris, or behind debris and rescue operations are delayed, their chances of survival decrease. Additionally, damage to the ventilation system may lead to oxygen shortages and toxic gases asphyxiation. The collapsed structure can also obstruct rescue teams' access, and the unstable conditions may result in further collapses during rescue efforts.

Furthermore, vehicle collisions or damage to electrical systems within the tunnel can significantly increase the risk of fire, and if hazardous materials are involved, there is also a potential explosion risk (Li et al, 2022; Tyagi, 2024; Pireddu, 2022).

Given these complex risk factors, tunnel failure and/or collapse pose severe dangers, necessitating a swift and well-coordinated emergency response. Comprehensive safety management to prevent accidents, along with the establishment of an effective

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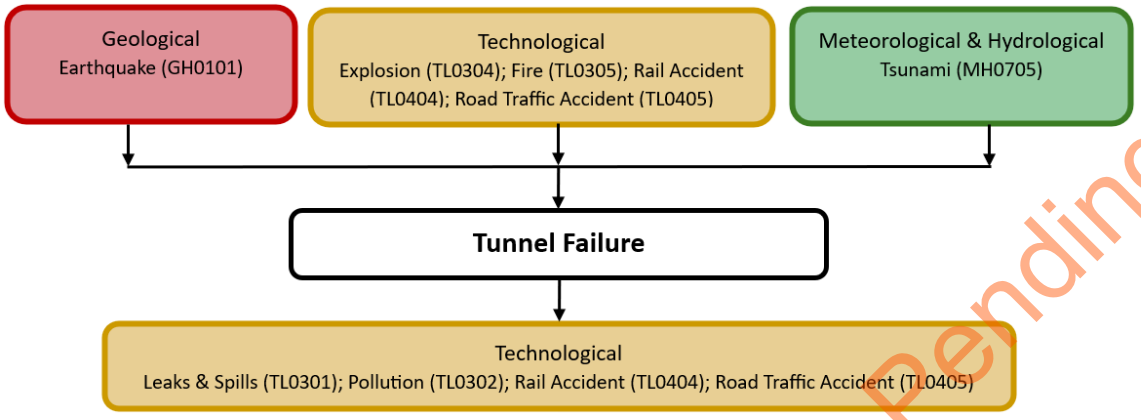
rescue system, is essential. Additionally, failure of a tunnel can result in substantial economic, social, and cultural impacts.

Multi-hazard Context: The figure below summarises common interactions between tunnel failure and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: Structural health monitoring over the lifecycle of the structure is used in some countries (Stepanovic et al., 2020). Structural Health Monitoring comprises the use of permanently installed sensors or instrumentation, combined with data analysis, to generate data that permits the continuous monitoring of structures such as bridges, dams, tunnels and buildings. This allows engineers to make timely, informed decisions regarding the monitored structure's integrity, detect structural defects, predict or estimate a structure's remaining life span and maximise the opportunity to operate the structure safely.

Risk Management in tunnelling requires a multi-disciplinary approach involving owners and operators, engineers and geologists contractors, and policymakers. Proprenter (2018) outlines key mitigation strategies:

- Advanced monitoring and early warning systems: AI-based predictive modelling (Zhang et al., 2023), geotechnical instrumentation, and real-time ground movement tracking
- Robust design and planning: Incorporating observational methods, stress modelling, and thorough site investigations
- Resilient infrastructure: High-performance linings, fire-resistant materials, and redundancy in ventilation and drainage systems
- Emergency response preparedness

The IMIA/ITA Code of Practice for Risk Management of Tunnel Works (2023) recommends fundamental good practices for avoiding losses and mitigating consequences including:

- Competency and resource adequacy among all stakeholders
- Risk-aware culture and open information sharing
- Defined risk allocation in contracts
- Timely resolution mechanisms for engineering disputes
- Thorough site investigations prior to awarding contracts
- Independent supervision and real-time monitoring during construction
- Integrated health and safety planning before excavation begins

The geological composition of tunnels is inherently intricate, and potential disasters can be severe, with many underlying risks (Cao et al., 2018; Zhu et al., 2020). Since tunnel collapses can result in significant casualties and property damage, risk prediction and early warning are essential. For example, soft rock tunnels have a high risk of collapse during construction. An early warning system helps detect and predict large deformation risks in advance, allowing for appropriate countermeasures. In assessing these risks, hydrogeological conditions, design factors, and construction factors serve as the primary indicators, while rock quality index, groundwater influence, and tunnel depth are considered secondary indicators. AI models can be utilized to monitor data, enabling the early detection of potential risks (Zhang et al., 2023).

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Preliminary – Corrections Pending

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Coordinating agency or organisation

International Tunnelling and Underground Space Association (ITA-AITES)

Preliminary – Corrections Pending

TL0214 / TECHNOLOGICAL / Flood

Drain and Sewer Flooding

Definition

Drain and sewer flooding is said to occur when sewage or foul water leaks from the sewerage system (through pipes, drains or manholes) or floods up through toilets, sinks or showers inside a building (Priestly, 2016).

Reference

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Preliminary – Corrections Pending

Annotations

Synonyms

Urban flooding, Drainage floods, Pluvial flood.

Additional scientific description

Drain and/or sewer flooding is a condition where wastewater and/or surface water escapes from or cannot enter a drain or sewer system and either remains on the surface or enters buildings. Drains and/or sewers can also undergo surcharge, which is a condition in which wastewater and/or surface water is held under pressure within a gravity drain or sewer system but does not escape to the surface to cause flooding (European Standard, 1995).

The United Nations Educational, Scientific and Cultural Organization (UNESCO) Intergovernmental Hydrological Programme (IHP) Urban Water Series, comprising a set of books on urban water management, addresses fundamental issues related to the role of water in cities and the effects of urbanisation on the hydrological cycle and water resources. Focusing on integrated approaches to sustainable urban water management, the Series provides valuable scientific and practical information for urban water practitioners, policymakers and educators throughout the world (UNESCO, 2011).

Water governance is usually highly decentralised, with overall responsibility held at the level of local government. However, there are still countries where the federal level or the state plays a key role in day-to-day operations (UNESCO / ARCEAI IdF, 2016).

In 1970, the United Nations identified three megacities. This number rose to 10 in 1990 and 28 in 2014. According to projections, there will be 41 megacities by 2030, many located in the world's least developed countries. Throughout history, these cities have often lacked both the time and the means to develop their urban services, including those relating to access to water, sanitation and rainwater drainage. This situation creates profound vulnerabilities and complex challenges. It is crucial that megacities share their experiences, to develop services capable of meeting the expectations of their inhabitants (UNESCO / ARCEAI IdF, 2016).

The study of hydrological extremes should consider that humans are part of the hydrologic system, both as agents of change and as beneficiaries of ecosystem services. While there have been significant advances in coupling hydrological and biogeophysical models over the past decade, these advances remain inaccessible to resource management decision-makers and other water sector professionals. With most river basins being no longer 'natural' as humans live and interact with the continuously changing hydrological system, there remains a need for a better understanding of the coupled human-ecosystems (UNESCO IHP, 2019).

Metrics and numeric limits

Not identified.

Key relevant UN convention / multilateral treaty

The European Committee for Standardization (CEN) provides hydraulic performance criteria in the European Standard EN 752 (CEN, 1996 & 1997).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Urban flooding caused by severe pluvial rainstorms has been reported for an increasing number of locations throughout the world (Grüning & Grimm, 2015; Schmitt & Scheid, 2020). For many years the design of urban drainage systems had been based upon concepts of design storm frequencies. Surface runoff and sewer flow values have been computed for site-specific rainfall intensities provided by national weather services or databases (IDF curves) and required sewer pipe slope and diameters have been selected. Little consideration had been given to the possible occurrence of sewer flooding and resulting damage in general, and in terms of site-specific factors of flood hazards (Schmitt & Scheid, 2020).

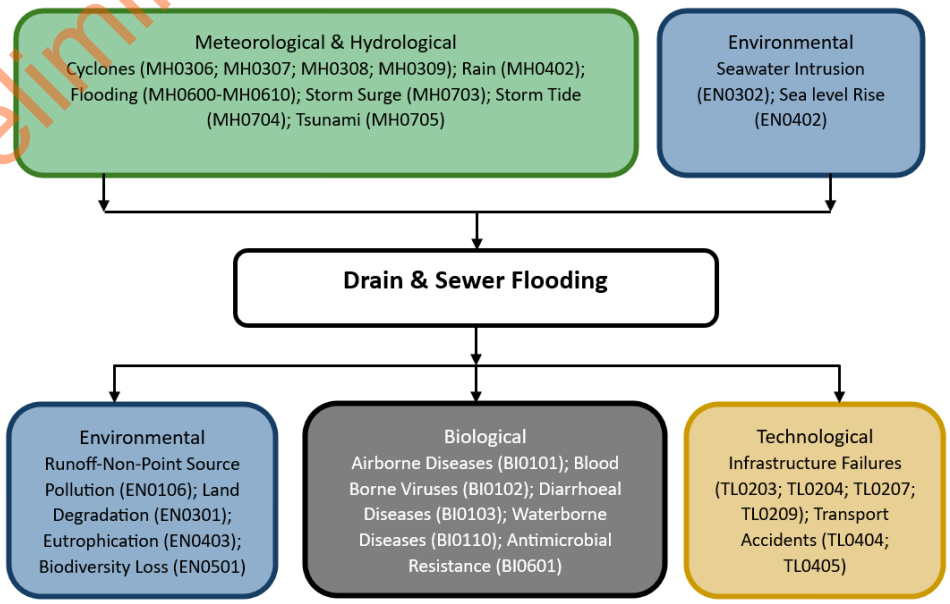
In some urban areas, Sewer systems and drains often become obstructed over time due to insufficient maintenance, resulting in sewer overflows during storms and flooding events (Dang et al., 2025). This challenge is particularly acute in densely populated cities across developing Asian countries, where drainage systems are often insufficient (Acosta-Coll et al., 2018).

Impacts: The severity and scale of urban flooding are influenced by factors such as rainfall intensity, duration, and frequency (Dang et al., 2025).

Sewage contains harmful microorganisms such as bacteria, viruses and protozoa. This contributes significantly to the spread of diseases such as typhoid and cholera and may increase the likelihood of contracting worm infections from soil contaminated by faeces. Flooding itself may displace populations and lead to further health problems (Howard et al., 2002). People need to avoid entering a flooded basement or lighting matches until the utility companies have shut off the gas and electric service.

Flooding in urban drainage systems occur at different stages of hydraulic surcharge depending on the drainage system (separate or combined sewers), general drainage design characteristics, as well as specific local constraints. When private sewage drains are directly connected to the public sewer system without backwater valves, the possible effects of hydraulic surcharge depend on the levels of the lowest sewage inlet inside the house, the sewer line, and the water level during surcharge, respectively. Whenever the water level in the public sewer exceeds the level of gravity inlets in the house below street level, flooding inside the house will occur due to backwater effects. In such a case flooding is possible, as well as surface flooding. In the same way, hydraulic surcharge in the sewer system might produce flooding on private properties via storm drains, when their inlet level is below the water level of the surcharged storm or combined sewer. In both cases, the occurrence of flooding, being linked directly to the level of inlets versus water level (pressure height) in the sewer can be easily predicted by hydrodynamic sewer flow simulations, assuming the availability of physical data for the private drains and public sewer system (Schmitt et al., 2002).

Multi-hazard Context: The figure below summarises common interactions between drain & sewer flooding and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Preliminary – Corrections Pending

Monitoring: No Information Available

Risk Management: Urban drainage systems are critical infrastructure for managing flood risks in cities. Climate change-induced intense rainfall reduces the time available for urban residents to respond during emergencies.

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Coordinating agency or organisation

Not Identified.

Preliminary – Corrections Pending

TL0215 / TECHNOLOGICAL / Flood

Reservoir Flooding

Definition

Man-made reservoirs, sometimes called artificial lakes, are important water sources in many countries around the world. In contrast to natural processes of lake formation, reservoirs are artificial, usually formed by constructing a dam across a river or by diverting a part of the river flow and storing the water in a reservoir. Reservoir flooding occurs as an uncontrolled release of water if a dam or reservoir fails (adapted from UNEP, 2000 and Defra and EA, 2014).

Reference

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Preliminary – Corrections Pending

Annotations

Synonyms

Reservoir overtopping.

Additional scientific description

Reservoir operation is an effective tool for water supply, hydropower generation, flood control and environmental or ecological enhancement. Dams are designed to safely pass floodwater, however, floods exceeding the design capacity of the dam spillways cause uncontrolled release of water over the dam crest, which is accompanied by a high risk of failure. Uncontrolled water passing over a dam crest can compromise the structural integrity of the dam, such as through erosion or cavitation, which can rapidly escalate to complete failure (US Department of the Interior Bureau of Reclamation, 2014).

Most dam failures or accidents occur in small and medium-sized reservoirs, primarily due to insufficient flood control standards and poor management. This underscores the importance of implementing measures to enhance the flood prevention capabilities of these reservoirs (Hou et al., 2024).

Metrics and numeric limits

Global metrics have not been identified. As an example, in England, 1.1 million properties are at risk of flooding from the structural failure of large, raised reservoirs and their associated dams (Defra, 2027).

Key relevant UN convention / multilateral treaty

UN Convention on the Law of the Non-navigational Uses of International Watercourses (UN Convention), adopted in 1997 (UNGA, 1997).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Heavy rain and increased glacier thaw cause increased inflow of water in the reservoir. As climate change causes increasing rainfall, larger flood peaks may result, which may increase the risk of overtopping (Qiu et al., 2021).

Impacts: The most significant risk of reservoir flooding is dam failure, which can lead to massive flooding in downstream areas. In August 2018, heavy rains caused the dam breach of the Sheyuegou Reservoir in Xinjiang, China, leading to 20 deaths and 8 missing (Ge et al., 2022)

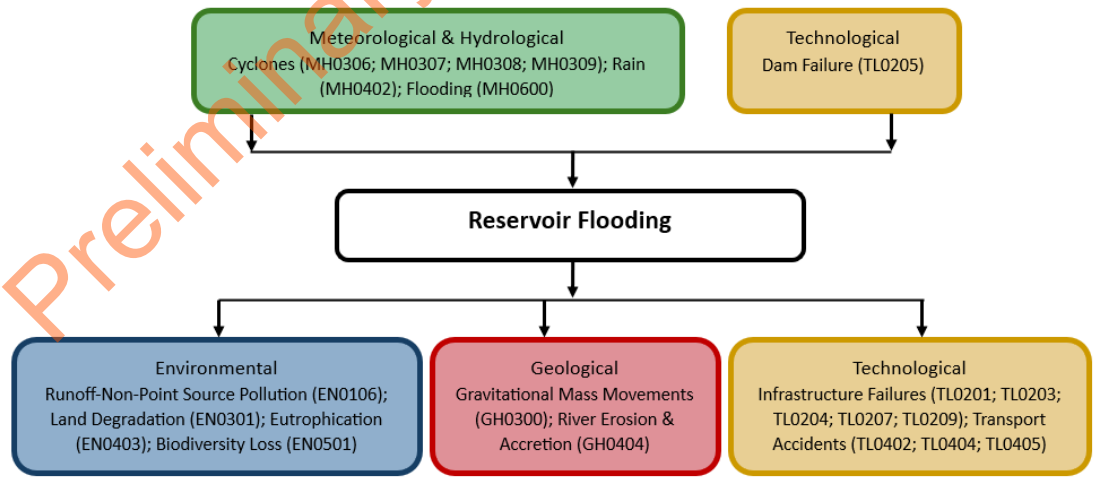
Reservoir flooding can cause economic losses, social and environmental impacts, loss of cultural resources and loss of life. Consequences of flooding are dependent on the exposed population and assets downstream, warning times, severity of flood and flood severity understanding (U.S. Department of the Interior Bureau of Reclamation, 2014).

The effects of flooding on health are extensive and significant, ranging from mortality and injuries resulting from trauma and drowning to infectious diseases and mental health problems (acute and long-term). While some of these outcomes are relatively easy to track, understanding of the human impact of floods is still limited. For example, it has been reported that two-thirds of deaths associated with flooding are from drowning, with the other third due to physical trauma, heart attacks, electrocution, carbon monoxide poisoning and fire. Often, only immediate traumatic deaths from flooding are recorded (WHO, 2013; Wu et al., 2024).

Morbidity associated with floods is usually due to injuries, infections, chemical hazards and mental health effects (acute as well as delayed) (WHO, 2013). Hypothermia may also be an issue, particularly in children if trapped in floodwaters for lengthy periods (WHO, 2021). There may also be an increased risk of respiratory tract infections due to exposure (loss of shelter, exposure to flood waters and rain). Power cuts related to floods may disrupt water treatment and supply plants thereby increasing the risk of water-borne diseases and may also affect the proper functioning of health facilities, including cold chain (WHO, 2021). Floods can potentially increase the transmission of communicable diseases, including water-borne diseases (such as typhoid fever, cholera, leptospirosis and hepatitis A) and vector-borne diseases (such as malaria, dengue and dengue haemorrhagic fever, yellow fever, and West Nile Fever) (WHO, 2021).

The longer-term health effects associated with a flood are less easily identified. They include effects due to displacement, destruction of homes, delayed recovery, and water shortages (WHO, 2013).

Multi-hazard Context: The figure below summarises common interactions between reservoir flooding and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring reservoir flooding. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Preliminary – Corrections Pending

Which institution(s) produce(s) Disaster Risk Data/Information?	Water Management Agencies, Electricity-producing Companies
How is the Hazard Observed/Monitored/Forecast?	Water gauges monitor the water level in the reservoir. Sensors monitor vibrations, cracks, and other structural anomalies.

Risk Management: Provided a reservoir is properly maintained the likelihood of it failing and causing flooding is low. However, in the very unlikely event of a dam collapse, a large volume of water could be released, quickly flooding a large area and possibly causing significant property damage or loss of life.

In England, 1.1 million properties are at risk of flooding from the structural failure of large, raised reservoirs and their associated dams. The average age of these structures is 120 years, and the possibility of catastrophic failure may be expected to increase with age. A key factor in avoiding and minimising the impact of such a catastrophic failure is the ability to draw a reservoir down in the event of an emergency. This will reduce the load on the dam structure, reduce the likelihood of failure and, in the very worst outcome, minimise the impacts downstream in the event of failure. Reservoir drawdown is also important to allow inspection and maintenance of the structures retaining the reservoir. (Defra, 2017).

The optimal operation of reservoir flood control includes various constraints such as upstream and downstream flood control, dam safety, and irrigation needs (Dai & She, 2023). The timing and precision of decisions regarding when to open the reservoir gates are crucial. Any delay in this decision can result in dam damage due to excess water, potentially causing flash floods in nearby areas (Doi et al., 2020).

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Preliminary – Corrections Pending

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Coordinating agency or organisation

Not identified

Preliminary – Corrections Pending

TL0301 / TECHNOLOGICAL / Industrial Failure

Leaks and Spills

Definition

A leak or a spill is an incident involving the uncontrolled release of a toxic substance, potentially resulting in harm to public health and the environment. Chemical incidents can occur as a result of natural events or as a result of accidental or intentional events. These incidents can be sudden and acute or have a slow onset when there is a 'silent' release of a chemical. Leaks and spills can range from small releases to full-scale major emergencies (adapted from WHO, no date).

Reference

WHO, no date. Chemical incidents. World Health Organization (WHO). www.who.int/health-topics/chemical-incidents Accessed 14 February 2025

Preliminary – Corrections Pending

Annotations

Synonyms

None Identified

Additional scientific description

Different hazardous chemicals may be released during leaks and spills, including but not limited to gases (CH0300, CH0400), heavy metals (CH0100), pesticides (CH0501), persistent organic pollutants (CH0500), dioxins (CH0502), and hydrocarbons (CH0203). Three notable examples of technological incidents involving a chemical leak and/or spill are the Seveso chemical leak, the Bhopal chemical leak and the Exxon Valdez oil spill.

Seveso chemical leak: At approximately 12:37 on Saturday 10 July 1976, a bursting disc on a chemical reactor ruptured at the Icmesa chemical company, Seveso, Italy. Maintenance staff heard a whistling sound, and a cloud of vapour was seen from a vent on the roof. A dense white cloud, of considerable altitude drifted offsite. Among the substances in the white cloud was a small deposit of 2,3,7,8-tetrachlorodibenzo-p-dioxin), a highly toxic material. The release lasted for twenty minutes. Over the next few days, there was confusion due to the lack of communication between the company and the authorities in dealing with this type of situation. The nearby town of Seveso, located 15 miles from Milan, had 17,000 inhabitants. No human deaths were attributed to TCDD but many people fell ill. Thousands of animals in the contaminated area died and many thousands more were slaughtered to prevent TCDD from entering the food chain (HSE, no date).

Bhopal chemical leak: On 3 December 1984, more than 40 tons of methyl isocyanate gas leaked from a pesticide plant in Bhopal, India. The gas drifted over the densely populated neighbourhoods around the plant killing thousands of people immediately. The leak also had long-term effects on health, with estimates of over 15,000 people dying prematurely in the years following the leak. This event highlighted the need for enforceable international standards for environmental safety, preventative strategies to avoid similar accidents and industrial disaster preparedness (Broughton, 2005).

Exxon Valdez oil spill: On 24 March 1989, the oil tanker Exxon Valdez ran aground on a charted rock, Bligh Reef, in Alaska's northern Prince William Sound. More than 11 million litres of crude oil spilt, eventually polluting over 30,000 km^2 of coastal and offshore waters (Peterson et al., 2003).

Technological incidents such as chemical spills and leaks can be sudden and acute when hazardous chemicals are 'overtly' released into the environment. Some chemical leaks and spillages may also result in fires, explosions and contamination of land. The factors leading up to an incident include poor maintenance of manufacturing and storage equipment, lack of

regulation and/or poor enforcement of safety regulations, road traffic accidents, human error, natural events such as heavy rain, earthquakes, hurricanes, floods, and terrorism (WHO, no date).

Chemical spills and leaks are one of the issues addressed by the Food and Agriculture Organization of the United Nations (FAO). They report that spills and leaks from containers are a major problem in the storage and transport of pesticides (cf. CH0501). The main cause of these spills and leaks is rough handling which dents drums, weakens or splits seams and weakens closures (lids, caps, stoppers). Leaks also result from corrosion of the container, which may be accelerated by mechanical damage (dents may rupture drum linings). Corrosion may start internally, with the pesticide itself or its breakdown products being the primary cause. Alternatively, corrosion may begin externally, due to rusting in damp storage conditions or contamination from chemicals leaking from nearby containers. Rodents may damage paper, board or fibre containers. Termites may attack paper and card. Pesticides should be repacked in containers made of the same materials as the original containers because some chemicals are not compatible with different materials (FAO, no date).

Most chemical spill-related technological incidents occur at the interfaces between the transport, storage, processing, use, and disposal of hazardous chemicals, where these systems are more vulnerable to failure, error or manipulation. Exposure levels will in general be quite different for different people involved in a chemical incident (WHO, no date):

- *Employees and other on-site persons:* usually more than one exposure pathway, often inhalation (breathing) of smoke and vapours and skin contact from splashing and clean-up of chemicals.
- *Emergency services:* usually close to the emergency and involved in rescue, containment of chemicals, managing the impact of chemical spills; primary and secondary contamination of fire officers, ambulance officers and other emergency staff; secondary contamination of medical staff and other hospital patients of incomplete decontamination of casualties.
- *Public:* exposure via air, water, food, soil etc.

Metrics and numeric limits

Chemical spills and leaks are subject to various regulatory thresholds and measurement criteria depending on the substance and jurisdiction. For water contamination, metrics include Maximum Contaminant Levels (MCLs) established by environmental protection agencies. For example, the US EPA sets the MCL for benzene in drinking water at 0.005 mg/L.

Additionally, the Strategic Approach to International Chemicals Management (SAICM) provides an important policy framework that supports the prevention and management of chemical leaks and spills (UNEP, 2020).

Key relevant UN convention / multilateral treaty

While a single global treaty specific to chemical leaks and spills doesn't exist, several international frameworks contain relevant provisions:

- Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1989). At the time of writing, there were 187 parties to the Basel Convention. At its 14th meeting, the Conference of the Parties to the Basel Convention adopted decision BC-14/12 by which it amended Annexes II, VIII and IX to the Convention with the aim of enhancing the control of transboundary movements of plastic waste and clarifying the scope of the Convention as it applies to such waste.
- The Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in Inter- national Trade (1998). The Convention promotes shared responsibility between exporting and importing countries in protecting human health and the environment from the harmful effects of such chemicals and provides for the exchange of information about potentially hazardous chemicals that may be exported and imported.
- The Stockholm Convention on Persistent Organic Pollutants (2001). The Convention is a global treaty to protect human health and the environment from chemicals that remain intact in the environment for long periods, become widely distributed geographically, accumulate in the fatty tissue of humans and wildlife, and have harmful impacts on human health or on the environment

Regional Directive: Europe example: Directive 2012/18/EU of the European Parliament and of the Council of 4 July 2012 on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC Text with EEA relevance, Applies to European Commission Member States (European Parliament and Council, 2012). In Europe, the catastrophic accident in the Italian town of Seveso in 1976 prompted the adoption of legislation on the prevention and control of such accidents. The so-called Seveso-Directive (Directive 82/501/EEC) was later amended in view of the lessons learned from later accidents such as Bhopal, Toulouse or Enschede resulting in Seveso-II (Directive 96/82/EC). In 2012, Seveso-III (Directive 2012/18/EU) was adopted taking into account, among others, the changes in the European Union legislation on the classification of chemicals and increased rights for citizens to access information and justice. The Directive applies to more than 12,000 industrial establishments in the European Union where dangerous substances are used or stored in large quantities, mainly in the chemical and petrochemical industry, as well as in fuel

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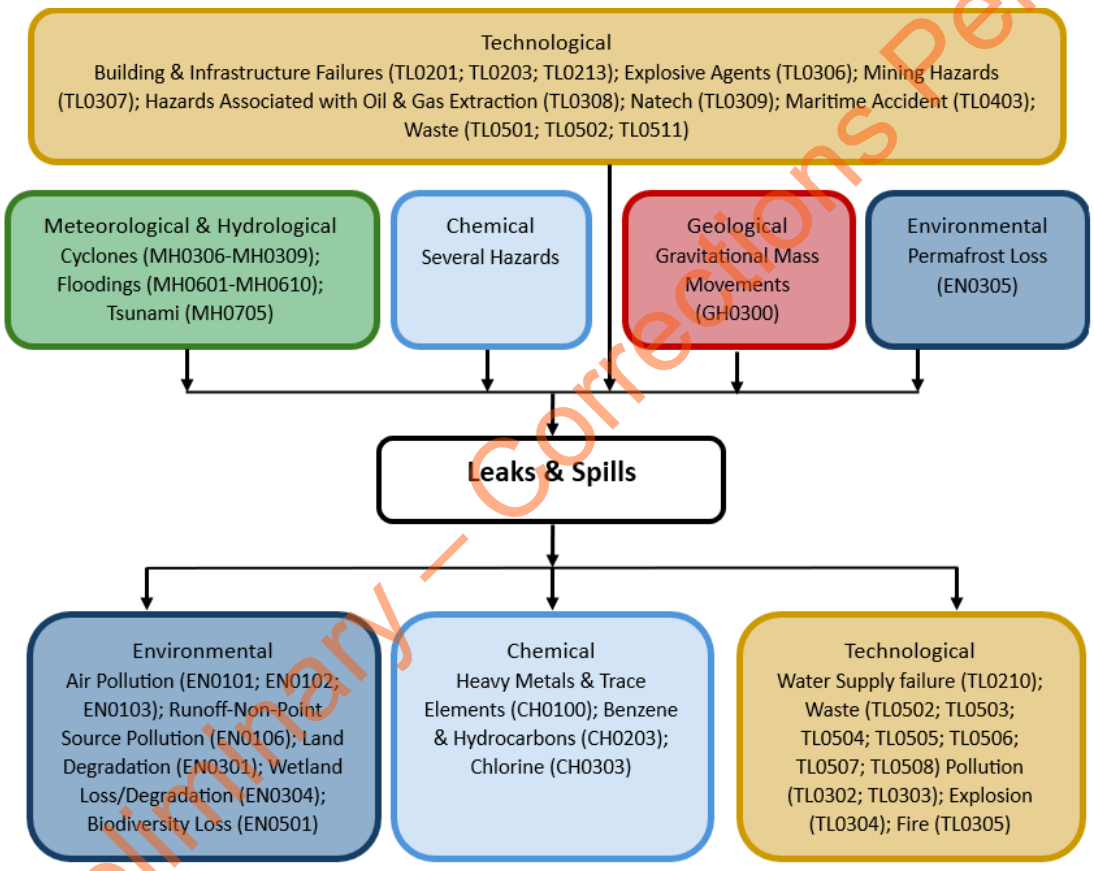
wholesale and storage (including the liquefied petroleum gas and liquefied natural gas) sectors (European Commission, 2020).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Leaks and spills can occur due to natural hazards, industrial accidents, or infrastructure failures, and they often create cascading risks. Several hazardous chemicals can be released during leaks and spills incidents, leading to different impacts.

Impacts: These incidents can trigger or worsen multiple hazards. They generally affect environmental health, human health or both. Air, water and soil pollution leading to environmental degradation and biodiversity loss are often observed. Damages to health vary depending on the chemical release but include skin damage, eye damage, respiratory issues, sometimes leading to death, either immediately after the event, or sometime later.

Multi-hazard Context: The figure below summarises common interactions between leaks & spills and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



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Monitoring: The section and the table below offer an overview of monitoring arsenic. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce Disaster Risk Data/Information?	Private companies managing industrial facilities (production and/or storage); Environmen protection agencies
How is the Hazard Observed/Monitored/Forecast?	Monitoring systems use sensors, satellite data, AI, or remote sensing technologies to identify lea in pipelines, industrial sites, or natural environments before they cause significant damage. For example, marine oil spills can be detected using synthetic aperture radar (SAR) images captured the European Sentinel-1 satellite. A trained deep learning model identifies oil slicks in the SAR images, which are then segmented into binary masks to analyse their extent and characteristics. Finally, the system simulates the trajectory of the oil spill based on wind and ocean currents to predict its movement (Yang et al, 2024).

Risk Management: Risk management measures can be grouped under the categories: prevention and control, preparedness

and response.

Prevention and control: Being aware of chemical incident-related hazards: locating chemical sites away from centres of population; registration of all chemicals in commercial establishments with a hazard inventory to ensure rapid identification of the released chemical; regular evaluation of plans and their implementation; inspection/monitoring, and enforcement of safety measures; reducing the amounts of chemicals stored; appropriate labelling of all chemicals; conducting response drills; rapid notification of the chemical incident emergency services in the event of a chemical release; regular surveillance and standardised reporting of incidents, including the small, commonly occurring incidents; measures to decontaminate land or water already contaminated by waste disposal; measures to prevent or contain any fire-fighting water run-off; and construction of drainage ditches or holding tanks to contain liquid chemicals (WHO, no date; UNEP/OCHA, 2023).

In any chemical incident, there are a number of essential steps to go through as part of the chemical incident plan. These steps include alerting the emergency services; assessment of actions and management options; environmental monitoring; public information and public warnings; advice on protection; sheltering or evacuation; other interventions to protect public health; and organising registers and samples as required (WHO, no date; National CBRN Centre, 2016; UNEP/OCHA, 2023).

Preparedness: Careful planning and thorough preparedness are prerequisites for an effective response to chemical incidents. Public authorities, at all levels, and the management staff of installations where hazardous chemicals are produced, stored etc. should establish emergency preparedness plans. All responsible parties should ensure that manpower, equipment, and financial and other resources necessary to carry out emergency plans are readily available for immediate activation in the event, or imminent threat of an accident. In addition, all personnel involved in the emergency response process should be adequately educated and trained (WHO, no date; National CBRN Centre, 2016; UNEP/OCHA, 2023).

Response: Depending on the type of contaminant and if an acute or a chronic contamination incident and the level of potential exposure from chemical leaks and spills consider, if appropriate, setting up risk zones. These are usually established around an incident:

- The hot zone is the area where first responders must use protective equipment to prevent primary contamination and is the area with actual or potential contamination and the highest potential for exposure.
- The warm zone, which surrounds the hot zone, is the area where appropriate personal protective equipment must be worn to prevent secondary contamination. The warm zone is an area uncontaminated by the initial release of a substance, which becomes contaminated by the movement of people or vehicles. The warm zone will be extended to include the area of decontamination activity. These areas cannot be guaranteed as free from contamination.
- The cold zone is the uncontaminated area between the inner cordon and the outer cordon where it has been assessed that there is no immediate threat to life.
- The decontamination line separates the warm zone from the cold zone, which is the area free from contamination (National CBRN Centre, 2016).

Consider contacting the nearest Poisons Centre in case advice on diagnoses and treatment of chemical poisonings is needed. Also consider setting up a public health team which, in the case of a spill-related chemical incident, will provide accident and emergency departments with information about the nature of the chemicals(s), any precautions to be taken, and information about secondary contamination and how to decontaminate casualties, staff and equipment. Further details and guidance can be found in the WHO manual on the public health management of chemical incidents (WHO, 2009).

Designed to help manage the recovery phase of a chemical incident where contamination has affected food production systems, inhabited areas and water environments, further information can be found in the UK recovery handbook for chemical incidents (PHE, 2020).

Community-based monitoring programs represent an important complementary approach to institutional and technological monitoring systems. Local communities often detect early warning signs of leaks through observations of environmental changes like unusual odours, water discolouration, or vegetation stress. Establishing formal mechanisms for community reporting, combined with training on basic observation protocols, can create valuable distributed monitoring networks. These approaches are particularly important in regions with limited institutional capacity or remote areas where technological monitoring coverage may be incomplete.

Guidance on risk communication strategies during a chemical leak and spill incidents should be effective, transparent, and timely communication is essential for reducing public exposure, maintaining trust, and facilitating cooperation with protective measures. Risk communication should be tailored to different stakeholder groups, address scientific uncertainties honestly, and incorporate cultural factors affecting risk perception. The WHO's Emergency Risk Communication guidelines provide valuable frameworks to help authorities manage the critical information dimensions of chemical leak and spill events (WHO, 2017)

The World Health Organization (WHO) works closely with countries and partners to monitor and report on their emergency

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preparedness capacities for all hazards, including chemical incidents. Surveillance of diseases of possible chemical aetiology is a daily element in the WHO outbreak alert and response activities (WHO, no date). The WHO also convenes regional meetings to strengthen the global network of poison centres and thus facilitate emergency responses to chemical incidents. Guidance and training materials to strengthen preparedness for chemical incidents and emergencies have been developed in collaboration with the Organisation for Economic Co-operation and Development, the Inter-Organization Programme for the Sound Management of Chemicals, and relevant organisations in the United Nations system (WHO, no date). Additional resources include the WHO human health risk assessment toolkit for chemical hazards (WHO, ILO & UNEP, 2011) and the guidance document on evaluating and expressing uncertainty in hazard characterisation (WHO and IPCS, 2018).

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Coordinating agency or organisation

World Health Organization (WHO) with partners including the International Labour Organization and the United Nations Environment Programme

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TL0302 / TECHNOLOGICAL / Industrial Failure

Pollution

Definition

Pollution is the presence of substances and heat in environmental media (air, water, land) whose nature, location, or quantity produces undesirable environmental effects; and the activities that generate pollutants. (UN data, no date).

Reference

UN data, no date. Pollution. Environment Glossary / United Nations Statistics Division. https://data.un.org/Glossary.aspx?q=pollution Accessed 22 May 2025.

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Annotations

Synonyms

Contamination, pollutant, poison, toxin

Additional scientific description

Pollution today is pervasive and persistent. While the world has achieved significant economic growth over the past few decades, it has been accompanied by large amounts of pollution, with significant impacts on human health and ecosystems and the ways in which some of the major Earth system processes, such as the climate, are functioning. Though some forms of pollution have been reduced as technologies and management strategies have advanced, approximately 19 million premature deaths are estimated to occur annually as a result of the way societies use natural resources and impact the environment to support production and consumption. If consumption and production patterns continue as they are, the linear economic model of 'take-make-dispose' will seriously burden an already polluted planet, affecting current and future generations (UNEP, 2017).

Global pollution is rising due to rapid economic growth, population increases, and insufficient environmental management. This poses serious health risks for people and ecosystems, particularly in low- and middle-income countries. Contributing to these challenges, the global economy relies on deeply intertwined supply chains, sustained by more than 100 billion tons of raw materials entering the system each year. Intensive material consumption depletes natural resources and causes negative environmental impacts at every stage of the product lifecycle. Global waste is expected to increase to 3.4 billion tons by 2050 (World Bank, 2025).

Pollution of all types hinders development outcomes. Exposure to air pollution, water pollution, and hazardous chemicals and wastes like mercury, lead and persistent organic pollutants (POPs) causes debilitating and fatal illnesses, creates harmful living conditions, and destroys ecosystems. Pollution undermines sustainable economic growth, exacerbates poverty and inequality in both urban and rural areas, and significantly contributes to climate change. Poor people, who cannot afford to protect themselves from the negative impacts of pollution, end up suffering the most (World Bank 2025). Pollution can have a disproportionate and negative effect on the poor, the disadvantaged and the vulnerable. Pollution constitutes a significant impediment to achieving health, well-being, prosperity and the sustainable development goal of 'leaving no one behind' (UNEP, 2017).

Pollution is the largest environmental cause of disease and premature death. It is estimated to be several times more deaths than from AIDS, tuberculosis, and malaria combined. Global health crises, such as the COVID-19 pandemic, are reminders of the strong linkages between environment and health and of the need to address such linkages systematically. (World Bank, 2025).

Our food, air and water expose us to a complex mixture of chemicals and materials (UNEP, no date a) (see Chemical HIPS CH0100, CH0200. CH0300, CH0500, CH0501, CH0902). These chemicals have a wide range of effects on health. In 2012, the World Health Organization (WHO) estimated that 23% of all deaths worldwide, amounting to 12.6 million people, were due to environmental causes; with 90% occurring in low- to middle-income countries. In the same year, the burden of

disease from environmental factors related directly to pollution in terms of death, illness and disability was estimated at 345 million Disability Adjusted Life Years. More recently, a study indicated that pollution is currently the largest environmental cause of disease and death, responsible for an estimated 9 million premature deaths globally in 2015 (Landrigan et al., 2017). With the world population growing, the numbers of vulnerable groups exposed to pollutants will increase unless urgent pollution abatement policies are implemented, and actions taken at the local level (UNEP, 2017).

There is a critical need for system-wide transformations to prevent, reduce and control pollution, toward greater resource efficiency and equity, circularity and sustainable consumption and production, and improved ecosystem resilience to support cleaner and more sustainable development (UNEP, 2017).

Emerging pollutants such as PFAS, endocrine-disrupting compounds, and nanomaterials, are increasingly detected in water, air, and soil but remain under-regulated (UNEP, 2017). These can have chronic effects even at low concentrations.

Metrics and numeric limits

A range of metrics are available for the different sources of pollution hazards and include

- WHO sets global air quality guidelines (AQGs) based on the latest scientific evidence and health research to protect human health from the adverse effects of air pollution. These guidelines are designed to provide guidance for policymakers and governments in setting targets and implementing measures to reduce air pollution. The (AQG) serve as a global target for national, regional and city governments to work towards improving their citizen's health by reducing air pollution (WHO, 2021).
- WHO produces international norms on water quality and human health in the form of guidelines that are used as the basis for regulation and standard setting worldwide. The Guidelines for drinking-water quality (GDWQ) promote the protection of public health by advocating for the development of locally relevant standards and regulations (health-based targets), adoption of preventive risk management approaches covering catchment to consumer (Water Safety Plans) and independent surveillance to ensure that Water Safety Plans are being implemented and effective and that national standards are being met (WHO, 2022).
- WHO has published guidance on chemicals and health (WHO., no date a). More than 160 million chemicals are known to humans. About 40,000 to 60,000 of them can be found in commerce; 6000 of these account for more than 99% of the total volume of chemicals in commerce globally. In 2017, the chemical industry was the second largest manufacturing industry in the world and the trend is going upwards – chemicals sales are projected to almost double from 2017 to 2030. Chemicals, whether of natural origin or produced by human activities, are part of our environment. Manufactured chemicals include industrial and agricultural products such as pesticides, petroleum products and processed metals. Some chemicals are manufactured for specific uses, while others are unwanted by-products, including wastes, or products of combustion such as toxic gases and particles from industrial emissions and the burning of fuel. Levels of exposure and resulting health impacts are determined by social as well as biological factors. Men, women and children are exposed to different kinds and levels of chemicals and are exposed with different frequency. In addition, men, women and children vary in their physiological susceptibility to health effects from exposure to hazardous chemicals (WHO, 2024).
- WHO/ILO partnership focuses on promoting safe and healthy workplaces by managing the risks associated with hazardous chemicals. This is achieved through various tools and initiatives, including the International Chemical Safety Cards (ICSCs), which provide essential safety and health information on chemicals (ILO/WHO, 2025). The International Chemical Safety Cards (ICSCs) are data sheets intended to provide essential safety and health information on chemicals in a clear and concise way. The primary aim of the Cards is to promote the safe use of chemicals in the workplace. The main target users are workers and those responsible for occupational safety and health. The ICSCs project is a common undertaking between the International Labour Organization (ILO) and the World Health Organization (WHO), with the cooperation of the European Commission.

Key relevant UN convention / multilateral treaties includes:

The **Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal** (1989). At the time of writing, there were 187 parties to the Basel Convention. At its 14th meeting, the Conference of the Parties to the Basel Convention adopted decision BC-14/12 by which it amended Annexes II, VIII and IX to the Convention with the aim of enhancing the control of transboundary movements of plastic waste and clarifying the scope of the Convention as it applies to such waste. (Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, 1989.

The **Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade** (1998). The Convention promotes shared responsibility between exporting and importing countries in protecting human health and the environment from the harmful effects of such chemicals and provides for the exchange of information about potentially hazardous chemicals that may be exported and imported. (Rotterdam Convention on

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the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade, 1998)

The **Stockholm Convention on Persistent Organic Pollutants** (2001). The Convention is a global treaty to protect human health and the environment from chemicals that remain intact in the environment for long periods, become widely distributed geographically, accumulate in the fatty tissue of humans and wildlife, and have harmful impacts on human health or on the environment. (Stockholm Convention on Persistent Organic Pollutions (POPs), 2001)

The **Minamata Convention on Mercury** (UNEP, 2013). The convention was signed in 2013 and ratified in 2017 and draws attention to a global and ubiquitous metal that, while naturally occurring, has broad uses in everyday objects and is released to the atmosphere, soil and water from a variety of sources. Controlling the anthropogenic releases of mercury throughout its lifecycle has been a key factor in shaping the obligations under the Convention (UNEP, 2024 a).

The **Global Framework on Chemicals** – For a planet free of harm from chemicals and waste' was formally established at the fifth International Conference on Chemicals Management (ICCM5) in Bonn, Germany, held on September 25-29, 2023. The Bonn Declaration, a political statement developed through extensive informal consultations, was also adopted during ICCM5. The Global Framework presents a comprehensive plan with 5 strategic objectives and 28 targets to guide countries and stakeholders in jointly addressing the lifecycle of chemicals, including products and waste. The Global Framework is multi-stakeholder and multisectoral in nature and it encompasses the involvement of relevant stakeholders across the life cycle of chemicals at the local, national, regional, and global levels. It emphasizes the collaboration of governments, international technical agencies, civil society, and the private sector in areas such as phasing out harmful chemicals, enhancing capacity building, and establishing better connections across various sectors like health, safety, trade, agriculture, energy, and transport (UNEP, 2023).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Pollution is one of the great existential challenges of the Anthropocene epoch (Landrigan et al., 2017). Pollution, especially pollution caused by industrial emissions, vehicle exhausts, and toxic chemicals, has increased sharply in the past 500 years, and the greatest increases today are seen in low-income and middle-income countries (Landrigan et al., 2017). Pollution contributes to long-term ecosystem degradation, loss of biodiversity, and climate amplification. Black carbon, a short-lived climate pollutant, worsens glacial melt. Persistent pollutants can lead to endocrine disruption and immune suppression, affecting disease susceptibility over time (UNEP, 2023). These hazard drivers also cause indirect hazard linkages such as floods spreading industrial contaminants (Euripidou and Murray, 2004) and particulate pollution from wildfires exacerbating respiratory epidemics (Finlay et al, 2012).

Many organisations including the United Nations Environment Programme (UNEP), in partnership with other United Nations organisations, member states, scientists and communities at all levels have developed programmes addressing air pollution, water contamination, marine pollution, chemicals, plastics waste and space debris.

Impacts:

Air pollution: Killing an estimated 7 million people per year, air pollution is currently the biggest environmental health risk. Airborne pollutants are responsible for about one-third of deaths from stroke, chronic respiratory disease, and lung cancer, as well as one-quarter of deaths from heart attack (WHO, no date b). Air pollution also strongly influences climate and is generated from various sources, from cookstoves and kerosene lamps to coal-fired power plants, vehicle emissions, industrial furnaces, wildfires, and sand and dust storms. The problem is most acute in urban areas, particularly in Africa and Asia. In low- and middle-income countries, 98% of cities with more than 100,000 inhabitants fail to meet the WHO air quality guidelines. Addressing air pollution can bring significant benefits to economies, human health, and the climate. This underlies global efforts by UNEP to tackle air pollution by supporting cleaner fuels and vehicles, inspiring individuals and city leaders to act, strengthening laws and institutions, and developing affordable technologies to monitor air quality (UNEP, 2024 b).

Water contamination: UNEP states that once water is contaminated, it is difficult, costly, and often impossible to remove the pollutants (UNEP, 2016). Currently, 80% of global wastewater goes untreated and is contaminated by a wide range substances, from human waste to highly toxic industrial discharges. The type and amount of pollutants in freshwater determines its suitability for human uses such as drinking, bathing, and agriculture (UNEP, 2025 a). Pollution of freshwater ecosystems can also impact the habitat and quality of life of fish and other wildlife. This can include pathogens (largely from human and animal waste), organic matter (including nutrients from agricultural run-off such as nitrogen or phosphorus), chemical pollution (from irrigation, domestic wastewater and runoff of mines into rivers) and salinity. Plastics, and chemicals of emerging concern such as certain pharmaceutical products, are issues for which their extent and impacts on freshwater are largely unknown. A 2016 preliminary assessment of water quality in rivers in Latin America, Africa and Asia. A snapshot of the World's Water Quality estimated that severe pathogenic pollution affects around one-third of all rivers, severe organic pollution around one-seventh of all rivers, and severe and moderate salinity pollution around one-tenth of all rivers in these regions (UNEP, 2016),

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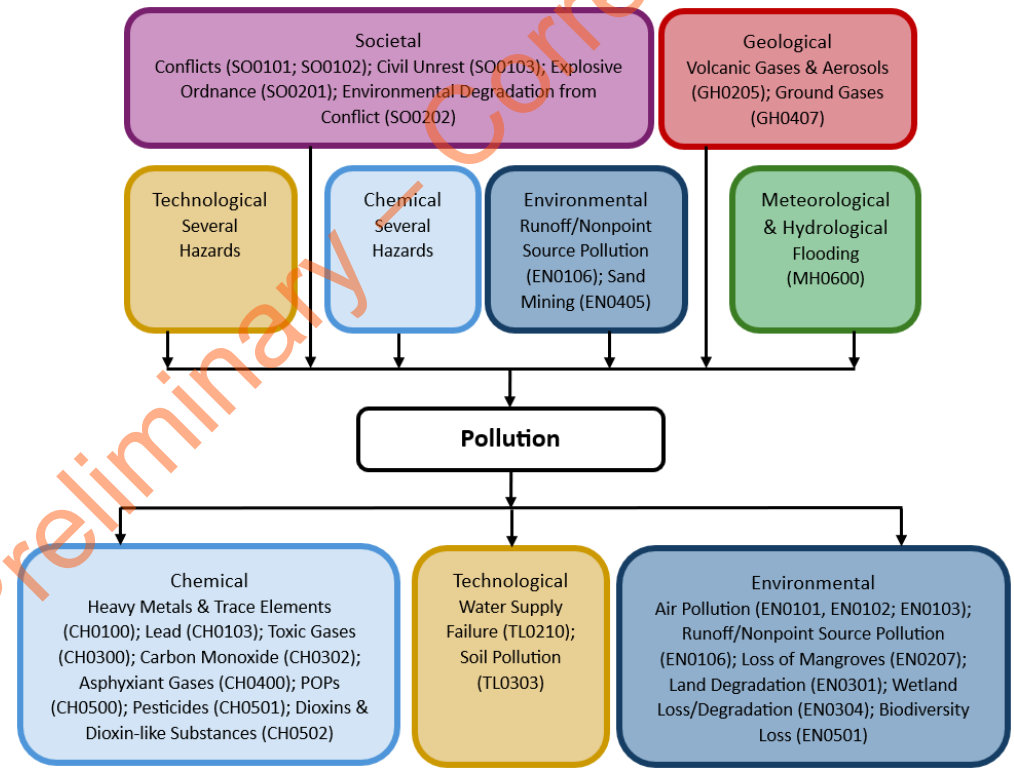
Marine pollution: Decades of relentless use of plastics across our economies has led to a seemingly unstoppable flow of plastics into the environment including out into the deep oceans. Largely a result of unsustainable production and consumption patterns and inadequate waste management, the challenge of plastics and other materials (UNEP, 2021). Sewage and wastewater, persistent organic pollutants (including pesticides), heavy metals, oils, nutrients and sediments - whether from rivers or discharged directly into coastal waters – can have significant impacts on human health and coastal ecosystems. The result is more carcinogens in seafood, more closed beaches, more red tides, and more beached carcasses of seabirds, fish and even marine mammals. One billion people in developing countries depend on fish as their primary source of protein, making them vulnerable to the chemicals they carry. Over the next two decades, this landmark agreement led to similar regional agreements in other Regional Seas (UNEP, 2021).

Chemicals, plastics and waste: As the world's population approaches 8 billion, the need for sound management of chemicals and waste is increasing. UNEP promotes joint approaches to the environment and health that demonstrate the economic, environmental and health advantages of sound chemical management for all concerned to stimulate policies and investment to reduce chemical risks to health and the environment (UNEP, 2025 b). Municipal solid waste generation is predicted to grow from 2.1 billion tonnes in 2023 to 3.8 billion tonnes by 2050. By 2025, the world's cities will produce more than three times the amount produced in 2009. Countries continue to address challenges linked to air, soil and water pollution and exposure to toxic chemicals under the auspices of multilateral environmental agreements (UNEP, 2025 b). An important chemical-generating pollution is plastic. The presence of plastic in the environment, in particular in marine sediments, can be seen as a stratigraphic indicator of the Anthropocene era (Zalasiewicz et al., 2016). Plastic pollution has mostly been studied in marine ecosystems (Eriksen et al., 2014), including seabirds, but freshwater ecosystems (Blettler et al., 2018) and soil ecosystems are also affected. The accumulation of plastic, especially micro- and nano-plastics is a threat to human health (UNEP, 2021)

Multi-hazard Context: The figure below summarises common interactions between pollution and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: Different mechanisms are available for some pollutants. As examples, for air pollution WHO recommends a variety of air quality monitoring methods, including both automatic and non-automatic approaches (WHO, no date b) and for drinking water extensive guidance is available (WHO, 2022)

Risk Management: Mechanisms for pollution/contamination prevention and control are essential and may include: local, national and global policies, strategies and legislation; planning and coordination (at all levels - national, subnational, local, including regional and transboundary); financial and human resources with a trained multidisciplinary workforce capacity; information and knowledge management for risk assessments, early warning and surveillance and technical guidance and

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support; mechanisms for risk communication; infrastructure support to include environmental and health services; and facilities for monitoring and evaluating drivers, impacts, outcomes and controls and reporting to local, national and international partners and organisations.

The WHO works closely with countries and partners to monitor and report on their emergency preparedness capacities for all hazards, including for chemical incidents relating to pollution and contamination. Surveillance of diseases of possible chemical aetiology is a daily element in the WHO's outbreak alert and response activities (WHO, 2020). Other health-related resources include the WHO Health Emergency and Disaster Risk Management Framework (WHO, 2019).

#BeatPollution is a UNEP campaign to stop the pervasive impact of pollution on people and the planet's health. The campaign drives rapid, large-scale and coordinated action for a cleaner, healthier and more sustainable future. Campaign activities show the impact of pollution on climate, nature and biodiversity, and health, and offer a platform to inspire thriving circular economies and enable the transition to a pollution-free planet (UNEP, 2025 c).

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Coordinating agency or organisation

Not identified.

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TL0303 / TECHNOLOGICAL / Industrial Failure

Soil Pollution

Definition

Soil pollution refers to the presence of a chemical or substance out of place and/or present in a soil at higher-than-normal concentration that has adverse effects on any non-targeted organism (Rodríguez-Eugenio et al., 2018).

Reference

Rodríguez-Eugenio, N., M. McLaughlin and D. Pennock, 2018. Soil Pollution: A Hidden Reality. Food and Agriculture Organization of the United Nations. www.fao.org/3/i9183en/i9183en.pdf Accessed 5 February 2025.

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Annotations

Synonyms

Contaminated Land, Special sites, Brownfield' sites, Soil contamination.

Additional scientific description

Soil plays a key role in food production and food quality, in climate regulation and in the provision of raw materials and other resources. Notwithstanding the enormous scientific progress made to date, protection and monitoring of soil conditions at national and global levels still face complicated challenges impeding effective on-the-ground policy design and decision-making (FAO, 2018).

Human activities over thousands of years have left a legacy of polluted soils worldwide. Much of it is local soil contamination which occurs commonly in connection to past and present mineral extraction, industrial activities, waste management and disposal, and includes remnants of hazardous materials such as obsolete pesticides. Countless chemical agents, some of them highly persistent, are found at various levels in the ground and can enter groundwater and surface water, locally produced food, and can even become airborne (gases, vapours, dusts, particulates). Soil pollution and its adverse health effects have been documented in many cases, but the magnitude of the overall impact on human health is not known. This is in contrast to air or water pollution, for which reliable estimates of their impacts have been available for two decades (FAO, 2018).

Soil pollution has been identified as one of the main soil threats affecting global soils and the ecosystem services that they provide (FAO and ITPS, 2015). Soil pollution poses a serious risk to human health through direct contact (dermal exposure, inhalation of polluted soil particles, intentional ingestion of polluted soil) or indirectly, by consuming plants or animals that have accumulated significant amounts of soil contaminants (FAO, 2018). For example, in an area of Japan where soil has been contaminated with cadmium from zinc/lead mines, Itai-itai disease used to be widespread and is still seen in women over 50 years of age. Itai-itai disease is characterised by osteomalacia, osteoporosis, painful bone fractures and kidney dysfunction (WHO, 2019). Health risks associated with the widespread soil pollution by radionuclides released during the Chernobyl disaster in 1986 are an enduring memory for many people (Rodríguez-Eugenio et al., 2018).

Recent research has expanded our understanding of emerging soil contaminants, particularly microplastics and per- and polyfluoroalkyl substances (PFAS). These persistent pollutants present unique challenges due to their resistance to degradation and complex mobility patterns through soil matrices. Studies indicate that microplastics can alter soil structure, water retention capacity, and microbial communities (Han et al, 2024), while PFAS contamination has been linked to reduced soil fertility and potential bioaccumulation in food crops (Lasters et al, 2024). The interaction between these emerging contaminants and traditional soil pollutants creates complex mixtures with potentially synergistic toxic effects that current risk assessment frameworks may not adequately address

Despite efforts in many regions of the world to estimate the extent of soil pollution, the lack of harmonised and comprehensive

data at the national, regional and global level limits the mobilisation of economic resources to minimise soil pollution and to achieve public and private commitment to combating soil pollution. There is a need to translate sound scientific evidence into concrete actions to prevent, control and remediate soil pollution (FAO, 2018).

Remediation of polluted soils is essential, and research continues to develop novel, science-based remediation methods. Increasingly, expensive physical remediation methods such as chemical inactivation or sequestration in landfills are being replaced by science-based biological methods such as enhanced microbial degradation or phytoremediation (Rodríguez-Eugenio et al., 2018). The maintenance of soil health and the prevention and reduction of soil pollution are possible through promoting sustainable soil management practices, environmentally friendly industrial processes, reduction of waste generation, recycling and reuse of goods, and sustainable waste storage (FAO, 2018).

The risks to human health posed by contaminated soils are assessed by comparing a representative soil concentration with chemical-specific assessment criteria indicative of 'safe' levels of exposure. There is no international standard for deriving these criteria. For example, Jennings (2013) compared the range of American standards with standards used elsewhere around the world. A total of 5949 guidance values for 57 elements were identified across the US regulatory authorities and assessment criteria values were seen to have been published in at least 71 other United Nations member states.

Metrics and numeric limits

While no globally harmonized metrics exist, several widely used quantitative frameworks could be referenced. For instance, many jurisdictions employ soil screening values (SSVs) or environmental quality standards (EQS) that establish concentration thresholds for common contaminants.

- The Dutch Intervention Values establish remediation triggers at concentrations where soil functionality is seriously impaired (RIVM/NIPHE, 2001).
- The United States EPA's Regional Screening Levels (RSLs) provide risk-based concentration thresholds for residential and industrial land uses. (USEPA, 2024)
- The European Commission' Risk Assessment Guidance Document provides a framework for calculating predicted no-effect concentrations (PNECs) for soil ecosystems. (European Commission, 2003)

These frameworks typically consider factors including background concentrations, exposure pathways, target protection levels, and contaminant bioavailability.

Key relevant UN convention / multilateral treaty

United Nations (2015) Sustainable Development Goals (United Nations, 2015). The prevention of soil pollution could reduce soil degradation, increase food security, contribute substantially to the adaptation and mitigation of climate change, and contribute to the avoidance of conflict and migration. Therefore, by taking immediate actions against soil pollution, contributions to the achievement of almost all the Sustainable Development Goals (SDGs) are possible, with a significant impact on SDGs 1, 2, 3, 6, 9, 11, 12, 13, 14, 15 and 17 (FAO, 2018).

Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1989). At the time of writing, there were 187 parties to the Basel Convention (Basel Convention, 2011). At its fourteenth meeting, the Conference of the Parties to the Basel Convention adopted decision BC-14/12 by which it amended Annexes II, VIII and IX to the Convention with the objectives of enhancing the control of the transboundary movements of plastic waste and clarifying the scope of the Convention as it applies to such waste.

Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (1998). The Convention promotes shared responsibility between exporting and importing countries in protecting human health and the environment from the harmful effects of such chemicals and provides for the exchange of information about potentially hazardous chemicals that may be exported and imported.

Stockholm Convention on Persistent Organic Pollutants (2001). The Convention is a global treaty to protect human health and the environment from chemicals that remain intact in the environment for long periods, become widely distributed geographically, accumulate in the fatty tissue of humans and wildlife, and have harmful impacts on human health or on the environment.

Minamata Convention on Mercury (UNEP, 2013). The Convention is a global treaty to protect human health and the environment from the adverse effects of mercury, which includes a ban on new mercury mines, the phase-out of existing ones, the phase-out and phasedown of mercury use in a number of products and processes, control measures on emissions to air and on releases to land and water, and the regulation of the informal sector of artisanal and small-scale gold mining. The Convention also addresses interim storage of mercury and its disposal once it becomes waste, sites contaminated by mercury, and health issues.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Soils may be polluted following industrial accidents; overuse of pesticides and conflict may also occur. Soil can also be polluted during volcanic eruptions or by space debris. Different chemicals may be included in soil pollution.

Long-term interactions between soil pollutants and environmental systems create persistent and evolving risk scenarios.

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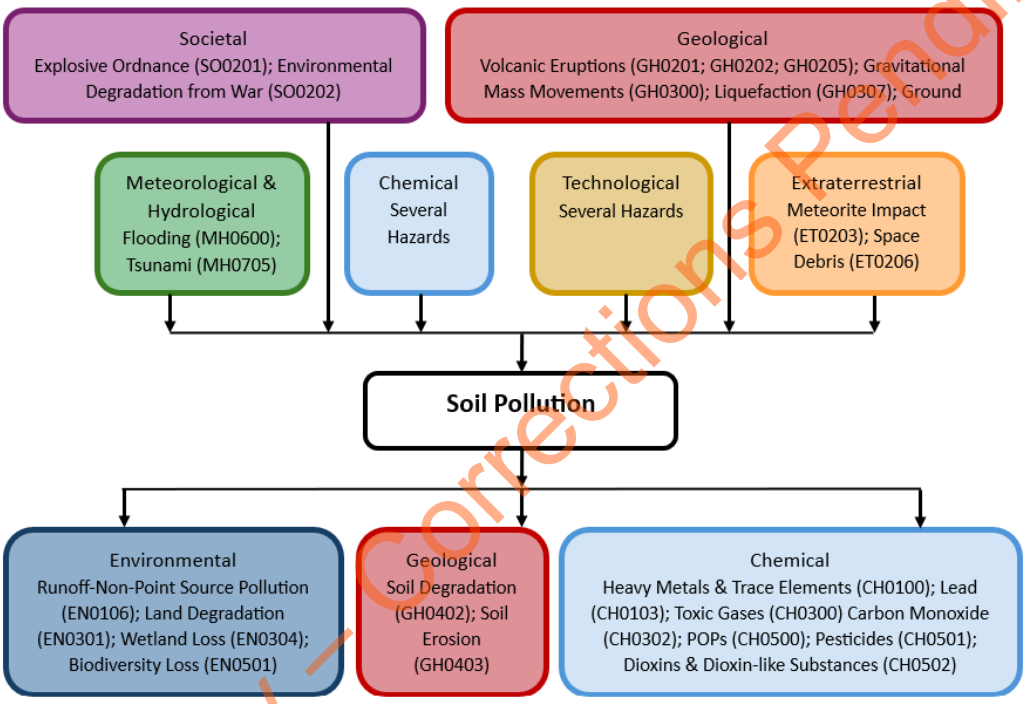
Contaminants like heavy metals and persistent organic pollutants can remain bioavailable in soils for decades or centuries, gradually migrating through watersheds and entering food chains. These slow-developing but significant interactions highlight the need for multigenerational monitoring and adaptive management strategies that account for changing environmental conditions over extended timeframes.

Impacts: Contaminated soil in areas exposed to landslides and flood risks can remobilize contaminants through physical (erosion) chemical (leaching) processes and issues such as dumping of waste. When a landslide occurs, contaminated soil may be displaced and flow into rivers or lakes, potentially spreading pollution. Soil and water contamination can also impact agriculture and ecosystems (Grimmer, 2024).

Multi-hazard Context: The figure below summarises common interactions between soil pollution and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



The interactions between soil pollution and other hazards often create complex cascading effects. For example, climate change-induced flooding can mobilize legacy contaminants from industrial sites into previously unaffected areas, while drought conditions can concentrate soil pollutants and increase their bioavailability. Urban development on contaminated brownfields may expose populations to multiple chemical stressors simultaneously, particularly in socioeconomically disadvantaged communities. Agricultural intensification practices that introduce pesticides, fertilizers, and antibiotics can interact with existing soil contaminants, potentially creating transformation products with unknown toxicological profiles. These multi-hazard scenarios require integrated risk assessment approaches that consider both the spatial and temporal dimensions of exposure.

Monitoring: No information Available

Risk Management: The Basel Convention promotes the environmentally sound management of hazardous waste to prevent soil contamination. Key activities include a household waste partnership and technical guidelines on managing hazardous waste like mercury and POPs. The Rotterdam Convention ensures the safe use of hazardous pesticides and chemicals by facilitating information exchange and enabling informed decisions on imports and exports. The Stockholm Convention aims to eliminate or reduce persistent organic pollutants (POPs) due to their toxicity and long-term environmental impact. Efforts include inventory development, phase-out strategies, best practices guidance, and technical assistance for national action plans (FAO&UNEP, 2021).

Key drivers for the assessment of contaminated land in the UK, primarily in the context of urban development, include remediation of contamination identified as impacting on groundwater quality or ecology and remediating brownfield sites for a change of land use and in particular development for housing. To this local management, using soil guidance values and land quality management is essential (European Commission, no date). Examples of local risk assessment and management include the sites of the 2000 Olympic Games in Sydney and the 2012 Olympic Games in London (Mead et al., 2013) successfully remediated contaminated land sites. However, further remediation could be required for any future land-use

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change involving more sensitive end-use, such as redevelopment for domestic gardens.

A number of assessment models and tools are available via CLARINET, the Concerted Action of the European Commission's Environment and Climate Research and Development Programme, which provides access to technical recommendations based on the concept of Risk Based Land Management for decision-making (EUGRIS, 2008). Also, in the European context, NICOLE is a European forum for the dissemination and exchange of good practice, practical and scientific knowledge and ideas to manage contaminated land in a sustainable and collaborative way.

The outcome document of the Global Symposium on Soil Pollution 'Be the Solution to Soil Pollution' (FAO, 2018) recommends an active and effective implementation of the Voluntary Guidelines for Sustainable Soil Management, which were developed through an inclusive process and endorsed by the 155th session of the FAO Council (Rome, 5 December 2016) (FAO, 2017). Their implementation is important in order to progress with the accomplishment of several of the sustainable soil management objectives, such as: to ensure that the availability and flows of nutrients are appropriate to maintain or improve soil fertility and productivity, and to reduce their losses to the environment; to reduce soil salinisation, sodification and alkalinisation; to ensure that water is efficiently infiltrated and stored to meet the requirements of plants and ensure the drainage of any excess; to ensure that contaminants are below toxic levels, i.e., those which would cause harm to plants, animals, humans and the environment; to guarantee that soil biodiversity provides a full range of biological functions; and to undertake soil management (FAO, 2018).

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Coordinating agency or organisation

Food and Agriculture Organization of the United Nations in partnership with Global Soil Partnership (GSP), Intergovernmental Technical Panel on Soils (ITPS), Basel, Rotterdam and Stockholm Conventions Secretariat (BRS Conventions); United Nations Environment Programme (UN Environment) and the World Health Organization (WHO).

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TL0304 / TECHNOLOGICAL / Industrial Failure

Explosion

Definition

Explosion-related technological incidents can be defined as accidental or intentional rapid energetic events that result in the actual or potential exposure of responders and/or members of the public to a chemical hazard (adapted from WHO, no date).

Reference

WHO, no date. Health Topics - Chemical Incidents World Health Organization (WHO). https://www.who.int/health-topics/chemical-incidents Accessed 13 February 2025.

Annotations

Synonyms

Blast, outburst

Additional scientific description

The effects of explosions can be devastating in terms of lives lost, injuries, damage to property and the environment, and to business continuity. Working with flammable liquids, dusts, gases and solids can be hazardous because of the risk of explosion and potentially a subsequent fire (HSE, no date). Explosion effects can include blast waves, fragment and debris throw, cratering and ground shock (USNRC, 2013).

Explosions can result from accidents at hazardous installations (such as chemical plants) and accidents while hazardous substances are in transport (such as by tankers or lorries). Notable examples of industrial explosions include those at the Piper Alpha oil platform in the North Sea in 1986 (Cullen, 1990), the ammonium nitrate (c.f. HIP CH0902) explosion in Beirut Lebanon in 2020 (Al-Hajj et al., 2021; El Sayed, 2020), the AZF fertiliser factory in Toulouse, France in 2001 (French Ministry of Sustainable Development, 2013) and the Buncefield oil storage depot in 2005 (HSE, 2011). Fires and explosions are frequently grouped together but an explosion can happen without a fire.

Explosion-related technological incidents can suddenly and overtly release hazardous chemicals (e.g. toxic gases (CH0300), persistent organic pollutants (CH0500), strong acids and bases (CH0901)) into the environment. The factors leading up to an incident can include poor maintenance of manufacturing and storage equipment, lack of regulation and/or poor enforcement of safety regulations, road traffic accidents, human error, natural events such as heavy rain, earthquakes, hurricanes, floods, and terrorism (WHO, no date).

Most explosion-related technological incidents occur at the interfaces between the transport, storage, processing, use, and disposal of hazardous chemicals, where these systems are more vulnerable to failure, error or manipulation. Exposure levels generally differ for the different people involved in a chemical incident (WHO, no date):

- *Employees and other on-site persons:* usually more than one exposure pathway, often inhalation (breathing) of smoke and vapours and skin contact from splashing and clean-up of chemicals.
- *Emergency services:* usually close to the emergency and involved in rescue, containment of chemicals, managing the impact of the explosion and extinguishing fires; primary and secondary contamination of fire officers, ambulance officers, and other emergency staff; secondary contamination of medical staff and other hospital patients of incomplete decontamination of causalities.
- *Public:* exposure via air, water, food, soil etc.

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Metrics and numeric limits

Vary with compounds - FEMA has published, in their Risk Management Series, a Primer for Design of Commercial Buildings to Mitigate Terrorist Attacks for providing protection to people and buildings (FEMA, 2003).

Key relevant UN convention / multilateral treaty

No globally agreed treaty identified.

Regional Directive: Europe example: Directive 2012/18/EU of the European Parliament and of the Council of 4 July 2012 on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC Text with EEA relevance, Applies to European Commission Member States (European Parliament and Council, 2012). In Europe, the catastrophic accident in the Italian town of Seveso in 1976 prompted the adoption of legislation on the prevention and control of such accidents. The so-called Seveso-Directive (Directive 82/501/EEC) was later amended in view of the lessons learned from later accidents such as Bhopal, Toulouse or Enschede resulting in Seveso-II (Directive 96/82/EC). In 2012, Seveso-III (Directive 2012/18/EU) was adopted taking into account, among others, the changes in the European Union legislation on the classification of chemicals and increased rights for citizens to access information and justice. The Directive applies to more than 12,000 industrial establishments in the European Union where dangerous substances are used or stored in large quantities, mainly in the chemical and petrochemical industry, as well as in fuel wholesale and storage (including the liquefied petroleum gas and liquefied natural gas) sectors (European Commission, 2020).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Explosions can result from natural hazards such as wildfires, lightning, volcanic eruptions or when critical infrastructures are damaged after an earthquake. They may also be caused by technological accidents such as fires, incidents in oil and gas extraction facilities, explosive agents, or inadequate storage of chemicals such as ammonium nitrate. Explosions may also occur during conflicts or criminal intent.

Impacts: Explosions affect the environment, through the release of toxic chemicals, and can damage or destroy buildings and infrastructure.

Damage and injury due to primary explosion effects are predominantly immediate with the potential of increasing damage in the long term (Finlay et al., 2012). Potential injuries can include lethal lung injury, brain traumata, hearing loss or violent displacement of the body (Finlay et al., 2012). Potential damages to the built environment can include the entire range from no or minor damage to complete collapse

Some individuals and sub-populations are at increased risk because they are more susceptible to the adverse effects of a given exposure. Among the potential causes of enhanced susceptibility are inherent genetic variability; age; gender; pre-existing disease (e.g., diabetes, asthma, chronic obstructive pulmonary disease); inadequate diet; occupational, environmental or lifestyle factors (e.g., smoking); and stress and inadequate access to health care (WHO, no date).

In most cases the mechanisms and health outcomes of exposure are unknown. Symptoms may present differently depending upon the explosion, any products of combustion, and chemicals and other materials involved in the explosion. In general, adverse health outcomes to toxic chemical exposure include:

- Effects that are local or arise at the site of contact with the products of combustion and chemicals, such as bronchoconstriction from respiratory irritants, or irritation of the skin and eyes by gases, liquids and solids.
- Effects that are systemic or affect organ systems remote from the site of absorption, such as depression of the central nervous system from inhalation of solvents, or necrosis of the liver from the inhalation of carbon tetrachloride.
- Effects on mental health arising from real or perceived releases, which depend on the psychosocial stress associated with an incident.

The time elapsing between exposure and the onset of symptoms can vary. Some effects, for example, eye and respiratory irritation or central nervous system depression, can occur rapidly, within minutes or hours of exposure (acute effects). Other effects, for example, congenital malformations or cancers, may take months or years to appear (delayed effects). The duration of the symptoms can also vary, from short-term to long-term or chronic. Chemical incidents (especially acts of terrorism) may also cause fear and anxiety in populations (WHO, no date).

Multi-hazard Context: The figure below summarises common interactions between explosions and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not

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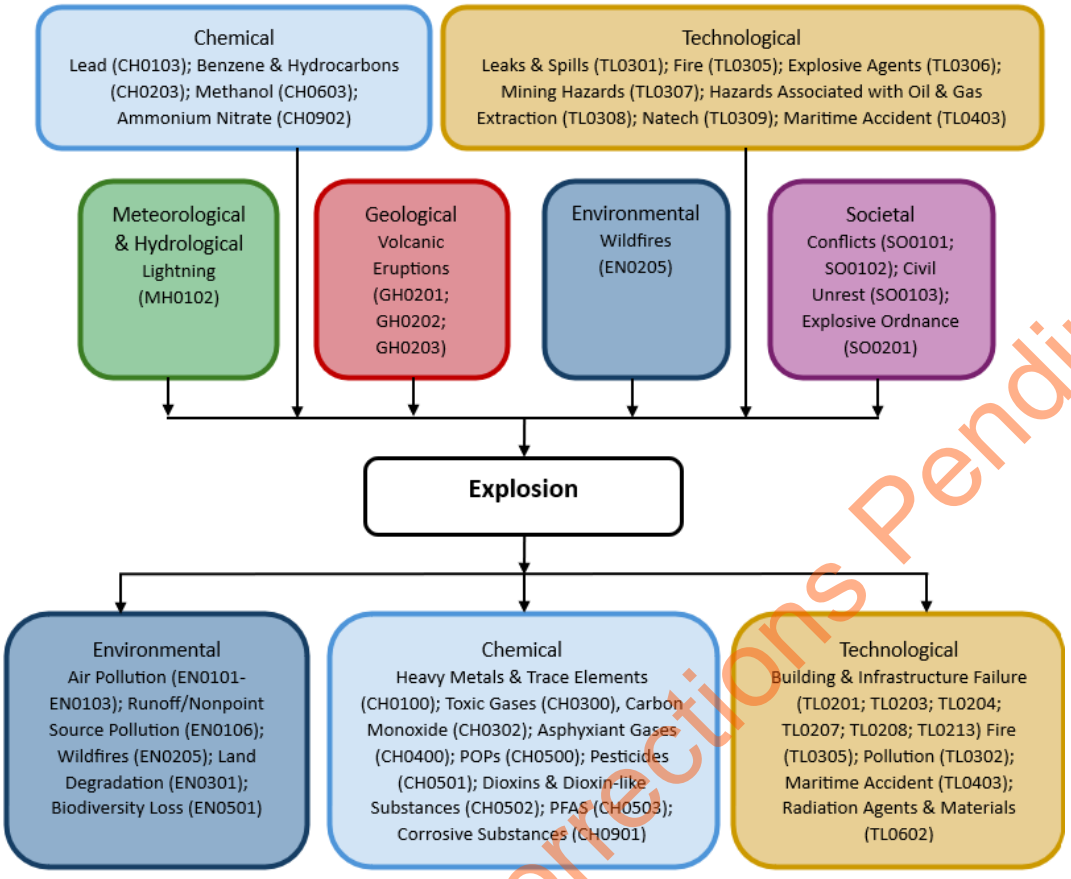
necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring explosion. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Private companies managing industrial facilities (production and/or storage), Military Command, Firefighting agencies, Disaster Risk Management Agencies
How is the Hazard Observed/Monitored/Forecast?	Explosion early warning systems are used in various settings, including industrial facilities, military zones, urban environments, and disaster-prone areas. For example, the Explosion Early Warning System (EWS) used in the oil and gas industry is equipped with sensors such as gas, flow, and temperature sensors. It aims to effectively identify potential hazard zones and provide early warnings to nearby workers and industrial safety monitoring teams. Through real-time monitoring and data analysis, the system optimises safety protocols and prevents casualties and asset damage caused by gas leaks. This approach enhances worker safety in modern industrial environments and contributes to the protection of critical energy resources (Padmaa et al, 2024).

Risk Management: Risk management measures can be grouped under the categories: prevention and control, preparedness and response (WHO, no date).

Prevention and control: Being aware of explosive-related hazards: locating chemical sites away from centres of population; registration of all chemicals in commercial establishments with a hazard inventory to ensure rapid identification of the released chemical; regular evaluation of plans and their implementation; inspection/monitoring and enforcement of safety measures; reducing the amounts of chemicals stored; appropriate labelling of all chemicals (using the Globally Harmonized System of Classification and Labelling of Chemicals (GHS - UNECE no date); appropriate segregation of incompatible chemicals; rapid notification of the chemical incident emergency services in the event of a chemical release; regular surveillance and standardised reporting of incidents, including the small, commonly occurring incidents; measures to decontaminate land or water already contaminated by waste disposal; measures to prevent or contain any fire-fighting water run-off; and construction of drainage ditches or holding tanks to contain liquid chemicals.

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In any chemical incident, there are a number of essential steps to go through as part of the chemical incident plan, including control of precursors for manufacturing high explosives. In approximate chronological order, these are: alerting the health care services; best outcome assessment of actions and management options; environmental monitoring; public information and public warnings; advice on protection; sheltering or evacuation; other interventions to protect public health; and organising registers and samples.

Preparedness: Careful planning and thorough preparedness are prerequisites for an effective response to chemical incidents. Public authorities, at all levels, and the management staff of installations where hazardous chemicals are produced, stored etc. should establish emergency preparedness plans, and conduct response drills. All responsible parties should ensure that manpower equipment, and financial and other resources necessary to carry out emergency plans are readily available for immediate activation in the event, or imminent threat of an accident. In addition, all personnel involved in the emergency response process should be adequately educated and trained.

R*esponse*: Depending on the level of potential exposure, risk zones are usually established around an incident:

- The hot zone is the area where first responders must use protective equipment to prevent primary contamination (National CBRN Centre, 2016).
- The warm zone, which surrounds the hot zone, is the area where appropriate PPE must be worn to prevent secondary contamination.
- The cold zone is the uncontaminated area between the inner cordon and the outer cordon where it has been assessed that there is no immediate threat to life.
- The decontamination line separates the warm zone from the cold zone.
- A vulnerable zone (in effect a potential hot zone) can be declared, which is the area likely to be contaminated if the emergency response action is not successful. The population within the vulnerable zone includes the resident population as well as the working population (in the plant and in the area), and other populations in the area at certain times, such as motorists, tourists and visitors to entertainment facilities.

Consider contacting the nearest Poisons Centre in case advice on diagnoses and treatment of chemical poisonings is needed. Also consider setting up a public health team which, in the case of an explosion-related chemical incident, will provide accident and emergency departments with information about the nature of the chemicals(s), any precautions to be taken, and information about secondary contamination and how to decontaminate casualties, staff and equipment. Further details and guidance can be found in the WHO manual on the public health management of chemical incidents (WHO, 2009).

Designed to help manage the recovery phase of a chemical incident where contamination has affected food production systems, inhabited areas and water environments, further information can be found in the UK recovery handbook for chemical incidents (PHE, 2020).

The WHO works closely with countries and partners to monitor and report on their emergency preparedness capacities for all hazards, including chemical incidents. Surveillance of diseases of possible chemical aetiology is a daily element in the WHO outbreak alert and response activities (WHO, no date). The WHO also convenes regional meetings to strengthen the global network of poison centres and thus facilitate emergency responses to chemical incidents. Guidance and training materials to strengthen preparedness for chemical incidents and emergencies have been developed in collaboration with the Organisation for Economic Co-operation and Development, the Inter-Organization Programme for the Sound Management of Chemicals, and relevant organisations in the United Nations system (WHO, no date). Additional resources include the WHO human health risk assessment toolkit for chemical hazards (WHO, ILO & UNEP, 2011) and the guidance document on evaluating and expressing uncertainty in hazard characterisation (WHO & IPCS, 2018).

Preliminary – Corrections Pending

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Coordinating agency or organisation

World Health Organization (WHO) with partners including the International Labour Organization and the United Nations

Preliminary — Corrections Pending

Environment Programme.

Preliminary – Corrections Pending

TL0305 / TECHNOLOGICAL / Industrial Failure

Fire

Definition

Fire-related technological incidents can be defined as accidental or intentional events that result in the actual or potential physical damage to property and exposure of responders and/or members of the public to a chemical hazard (adapted from WHO, no date)

Reference

WHO, no date. Health Topics - Chemical Incidents World Health Organization (WHO). https://www.who.int/health-topics/chemical-incidents Accessed 13 February 2025.

Annotations

Synonyms

None Identified

Additional scientific description

The effects of fires or explosions can be devastating in terms of lives lost, injuries, damage to property and the environment, and business continuity. Working with flammable liquids, dusts, gases and solids can also lead to an increase in the risk of fire and explosion (HSE, no date). Fire-related incidents may also involve explosions, spills, leaks and contamination.

Notable examples of fire-related technological incidents include the Piper Alpha oil platform disaster, UK, 1986 (Cullen, 1990), the Kuwaiti oil fires in 1991 (Al-Damkhi et al., 2009), the World Trade Centre fires in New York, USA in 2001 (Klitzman & Freudenberg, 2003), and the explosion and fire at the Buncefield oil storage depot, UK, in 2005 (HSE, 2011).

Fire-related technological incidents can be sudden and acute, when hazardous chemicals, including toxic gases (cf HIP CH0300), are 'overtly' released into the environment. The factors leading up to an incident include poor maintenance of manufacturing and storage equipment, lack of regulation and/or poor enforcement of safety regulations, road traffic accidents, human error, natural events such as heavy rain, earthquakes, hurricanes, and floods, and terrorism (WHO, no date).

Most fire-related technological incidents occur at the interfaces between the transport, storage, processing, use, and disposal of hazardous chemicals, where these systems are more vulnerable to failure, error or manipulation. Exposure levels will in general be quite different for different people involved in a chemical incident (WHO, no date):

- *Employees and other on-site persons*: usually more than one exposure pathway, often inhalation of smoke, vapour and skin contact from splashing and clean-up of chemicals.
- *Emergency services*: usually close to the emergency and involved in rescue, containment of chemicals, managing the impact of fires; primary and secondary contamination of fire officers, ambulance officers, and other emergency staff; secondary contamination of medical staff and other hospital patients of incomplete decontamination of casualties.
- *Public*: exposure via air, water, food, soil etc.

Metrics and numeric limits

Vary with the cause of the fire. Not specific information available.

Preliminary – Corrections Pending

Key relevant UN convention / multilateral treaty

A globally agreed treaty was not identified.

Regional Directive: Europe example: Directive 2012/18/EU of the European Parliament and of the Council of 4 July 2012 on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC Text with EEA relevance, Applies to European Commission Member States (European Parliament and Council, 2012). In Europe, the catastrophic accident in the Italian town of Seveso in 1976 prompted the adoption of legislation on the prevention and control of such accidents. The so-called Seveso-Directive (Directive 82/501/EEC) was later amended in view of the lessons learned from later accidents such as Bhopal, Toulouse or Enschede, resulting in the Seveso-II (Directive 96/82/EC). In 2012 Seveso-III (Directive 2012/18/EU) was adopted ,taking into account, among others, the changes in the European Union legislation on the classification of chemicals and increased rights for citizens to access information and justice. The Directive applies to more than 12, 000 industrial establishments in the European Union where dangerous substances are used or stored in large quantities, mainly in the chemical and petrochemical industry, as well as in fuel wholesale and storage (including liquefied petroleum gas and liquefied natural gas) sectors (European Commission, 2020).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Fire has a complex multi-hazard context, resulting from various natural hazards and human-induced risks. For example, lightning and volcanic eruptions can trigger wildfires and fires in urban areas. Some fires may be driven by and / or involve flammable chemicals such as methanol (CH0603), and benzene and other hydrocarbons (CH0203). Fires may also result from explosions and occur during conflicts.

Impacts: Fire damage to buildings, especially ones with cladding, release toxic chemicals and smoke that affect people's health. Some individuals and sub-populations can also be at increased risk because they are more susceptible to the adverse effects of a given exposure. Among the potential causes of enhanced susceptibility are inherent genetic variability, age, gender, pre-existing disease (e.g., diabetes, asthma, chronic obstructive pulmonary disease), inadequate diet, occupational, environmental or lifestyle factors (e.g., smoking), stress and inadequate access to health care (WHO, no date).

In most cases the mechanisms and health outcomes of exposure are unknown. Symptoms may present differently depending upon the products of combustion and chemicals and other materials involved in the fire. In general, the adverse health outcomes of toxic chemical exposure may be:

- Effects that are local or arise at the site of contact with the products of combustion and chemicals, such as bronchoconstriction from respiratory irritants, or irritation of the skin and eyes by gases, liquids and solids (e.g., toxic gases, asphyxiant gases, carcinogens, dusts).
- Effects that are systemic or affect organ systems remote from the site of absorption, such as depression of the central nervous system from inhalation of solvents, or necrosis of the liver from the inhalation of carbon tetrachloride.
- Effects on mental health arising from real or perceived releases, which depend on the psychosocial stress associated with an incident.
- The time elapsing between exposure and the onset of symptoms can vary:
- Some effects, for example, eye and respiratory irritation or central nervous system depression, can occur rapidly, within minutes or hours of exposure (acute effects).
- Other effects, for example, congenital malformations or cancers, may take months or years to appear (delayed effects).

The duration of the symptoms can also vary, from short-term, to long-term or chronic. Chemical incidents (especially acts of terrorism) may also cause fear and anxiety in populations (WHO, no date).

Multi-hazard Context: The figure below summarises common interactions between fire and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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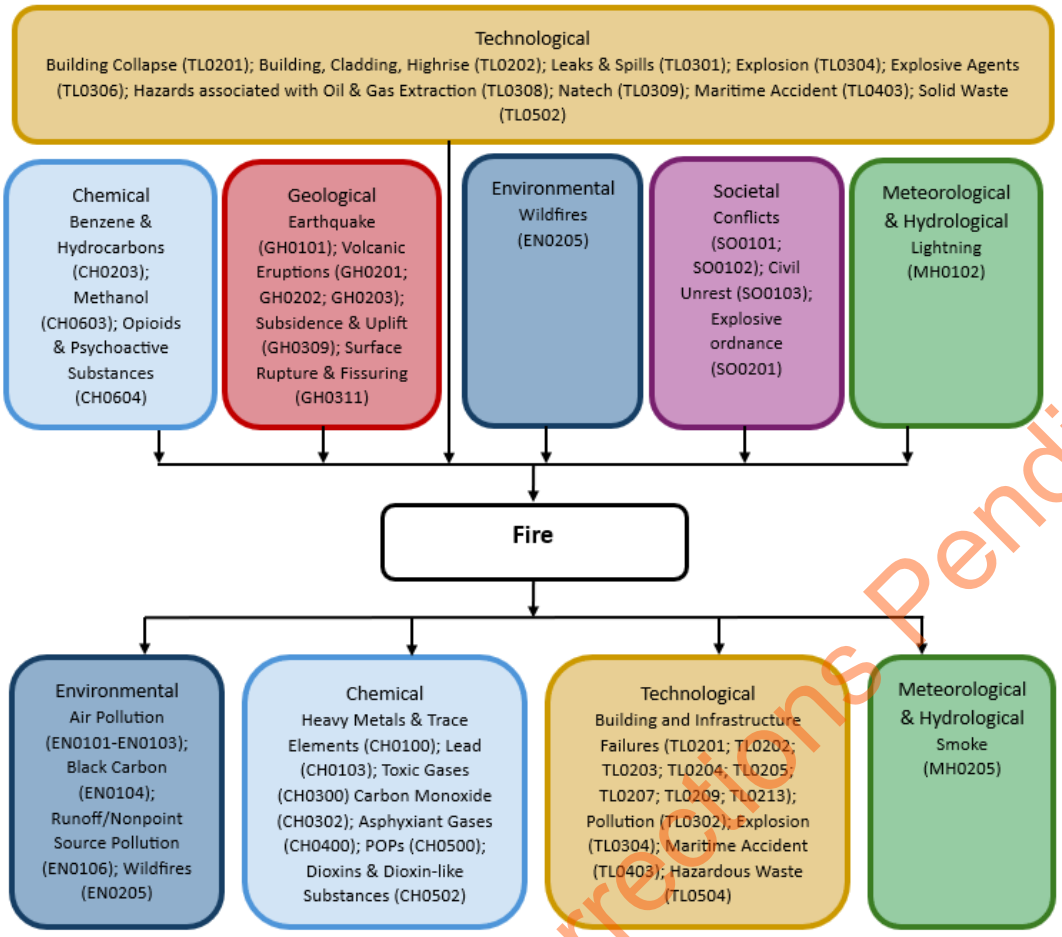

Monitoring: The section and the table below offer an overview of monitoring fire. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Private companies managing industrial facilities (production and/or storage); firefighting agencies.
How is the Hazard Observed/Monitored/Forecast?	The Fire Early Warning System (FEWS) is a critical safety system designed to detect fire hazards in the early stages and issue alerts to minimise casualties and property damage. This system utilises various sensors and technologies to monitor and analyse signs of fire in real-time. It continuously detects temperature, smoke, and gas concentrations, integrating multiple sensors such as smoke detectors, heat detectors, and flame detectors. Dryad Networks' Silvanet system combines gas sensors with artificial intelligence to detect wildfires at an early stage. This system consists of sensors connected via a wireless network and performs real-time data analysis and monitoring through a cloud platform (Jones, 2023). Additionally, in medical facilities, IoT-based fire early warning systems are implemented to reduce casualties and property loss (AL-Isawi et al., 2023). Satellites can provide alerting or location data for fires or plumes including those arising offshore. There are several systems for aggregating data and alerting including NASA's Fire Information for Resource Management System (FIRMS) https://firms.modaps.eosdis.nasa.gov/map/#m:advanced

Risk Management: The World Health Organization (WHO) recommends that risk management measures include: being aware of explosive-related hazards; locating chemical sites away from centres of population; the registration of all chemicals in commercial establishments with a hazard inventory to ensure rapid identification of the released chemical; regular evaluation of plans and their implementation; inspection/monitoring and enforcement of safety measures; reducing the amounts of chemicals stored; appropriate labelling of all chemicals; rapid notification of the chemical incident to emergency services in the event of a chemical release; regular surveillance and standardised reporting of incidents, including the small, commonly occurring incidents ones; measures to decontaminate land or water already contaminated by waste disposal; measures to prevent or contain any fire-fighting water run-off; and

Preliminary – Corrections Pending

construction of drainage ditches or holding tanks to contain liquid chemicals (WHO, no date).

In any chemical incident, there are a number of essential steps to go through as part of the fire-related chemical incident plan. These are in approximate chronological order: alerting the health care services; best outcome assessment of actions and management options; environmental monitoring; public information and public warnings; advice on protection; sheltering or evacuation; other interventions to protect public health; and organising registers and samples.

Preparedness: Careful planning and thorough preparedness are prerequisites for an effective response to chemical incidents. Public authorities, at all levels, and the management staff of installations where hazardous chemicals are produced, stored etc. should establish emergency preparedness plans. All responsible parties should ensure that manpower, equipment, and financial and other resources necessary to carry out emergency plans are readily available for immediate activation in the event, or imminent threat of an accident. All personnel involved in the emergency response process should be adequately educated and trained.

*Response: D*epending on the level of potential exposure, risk zones are usually established around an incident:

- The hot zone is the area where first responders must use protective equipment to prevent primary contamination (National CBRN Centre, 2016).
- The warm zone, which surrounds the hot zone, is the area where appropriate personal protective equipment must be worn to prevent secondary contamination.
- The cold zone is the uncontaminated area between the inner cordon and the outer cordon where it has been assessed that there is no immediate threat to life.
- The decontamination line separates the warm from the cold zone.

A vulnerable zone (in effect a potential hot zone) can be declared, which is the area likely to be contaminated if the emergency response action is not successful. The population within the vulnerable zone includes the resident population as well as the working population (in the plant and in the area), and other populations in the area at certain times, such as motorists, tourists and visitors to entertainment facilities. The nearest Poisons Centre should be contacted in case advice on diagnoses and treatment of chemical poisonings is needed.

To set up a public health team which, in case of a fire-related chemical incident, will provide accident and emergency departments with information about the nature of the chemicals(s), any precautions to be taken, and information about secondary contamination and how to decontaminate causalities, staff and equipment. Further details and guidance can be found in the WHO Manual: The Public Health Management of Chemical Incidents (WHO, 2009).

Designed to help manage the recovery phase of a chemical incident where contamination has affected food production systems, inhabited areas and water environments, further information can be found in the UK Recovery Handbook for Chemical Incidents (PHE, 2020).

The WHO works closely with countries and partners to monitor and report on their emergency preparedness capacities for all hazards, including chemical incidents. Surveillance of diseases of possible chemical aetiology is a daily element in WHO's outbreak alert and response activities (WHO, no date). The WHO also convenes regional meetings to strengthen the global network of poison centres and thus facilitate emergency responses to chemical incidents. Guidance and training materials to strengthen preparedness for chemical incidents and emergencies have been developed in collaboration with the Organisation for Economic Co-operation and Development, the Inter-Organization Programme for the Sound Management of Chemicals, and relevant organisations in the United Nations system (WHO, no date). Additional resources include the WHO human health risk assessment toolkit for chemical hazards (WHO, ILO & UNEP, 2011) and the guidance document on evaluating and expressing uncertainty in hazard characterisation (WHO & IPCS, 2018).

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Preliminary – Corrections Pending

Coordinating agency or organisation

World Health Organization (WHO) with partners including the International Labour Organization and the United Nations Environment Programme

TL0306 / TECHNOLOGICAL / Industrial Failures

Explosive agents

Definition

An explosive substance or agent is a solid or liquid substance (or mixture of substances) which is in itself capable, by chemical reaction, of producing gas at such a temperature and pressure and at such a speed as to cause damage to the surroundings. Pyrotechnic substances and mixtures are included even when they do not involve gases. Explosions can cause multiple severely injured casualties in a single incident (Adapted from UN 2023 and UK Parliament POSTNOTE 2011).

Preliminary – Corrections Pending

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UK Parliament POSTNOTE Explosive injury Number 395 December 2011 https://researchbriefings.files.parliament.uk/documents/POST-PN-395/POST-PN-395.pdf Accessed 14 March 2025

Annotations

Synonyms

Explosives, explosive substances

Additional scientific description

Explosive substances are commercially used in various industry applications, in ammunition items, and in improvised explosive devices which can be hazardous in storage and non-conflict settings. Ammonium nitrate is an explosive, and its inadequate storage has caused several explosions. As an example, the massive chemical detonation on August 4, 2020 in the Port of Beirut, Lebanon resulted in an uncontrolled fire in an adjacent warehouse which ignited ~2,750 tons of Ammonium Nitrate (AN), The blast supersonic pressure and blast resulted in 220 deaths and injured more than 6,500, with severe damage to the nearby dense residential and commercial areas (Al-Hajj et al., 2021).

Explosive agents are also included as the E of CBRNE which is the abbreviation commonly used to describe the use of Chemical, Biological, Radiological, Nuclear and explosive materials or weapons. The malicious use of such materials could cause significant harm or disruption (Goulart et al., 2022). Explosive agents are a subset of what is commonly referred to as conventional weapons. Technologically, there are many types of explosive materials, including bombs, artillery shells, grenades, missiles, landmines and improvised explosive devices, which are activated by the detonation of a high explosive substance (UNODA no date).

Types of weapons that are particularly problematic in terms of ammunition safety use and indirect fire weapons, such as artillery, rockets and mortars, weapons that fire in salvos, such as multi-launch rocket systems, large air-dropped bombs and surface-to-surface ballistic missiles. Such systems variously involve munitions with a large destructive radius, weapons with inaccurate delivery systems or weapon systems that deliver multiple munitions over a wide area (UNODA no date). A populated area is generally understood as a permanent or temporary concentration of civilians and/or civilian objects. A leading concern is the use of explosive weapons, in particular those with wide-area impacts, in populated areas. Many of these weapons were originally designed for use in open battlefields and are inherently indiscriminate when used in populated areas and therefore

result in increased civilian casualties and devastating humanitarian impacts (UNODA no date).

Explosive agents normally carry both the fuel and oxidizer needed for the process. Compounds with high nitrogen and oxygen content are often explosive. Goulart et al. (2022) report that there are three necessary components for an explosion to occur:

1. The fuel: a flammable substance, that can be oxidised to form highly stable small molecules such as nitrogen gas (N_2), carbon dioxide (CO_2), or water (H_2O). The formation of such stable molecules results in release of large amounts of energy and the rapidly moving small molecules are responsible for the damaging pressure wave(s).
2. An oxidant: often oxygen (O_2), or an oxygen-rich species such as nitrate ion, is required in high quantities and in combination with the flammable substance to produce an explosive atmosphere.
3. Ignition: Source a spark or high heat must also be present.

In summary, explosives can be described as:

- Primary explosives are substances or mixtures that can easily be detonated by a non-explosive simple initiating impulse such as a flame, impact, friction, heat, electricity or spark etc. They are mainly used in applications where it is desired to produce a shock wave for initiation of a less sensitive secondary explosive or a flame for initiation of propellants. Most of the primary explosives are highly sensitive to mechanical stimuli that make handling them very dangerous (Goulart et al., 2022).
- Secondary explosives are individual explosive compounds or formulations that are relatively insensitive to non-explosive stimuli. Secondary explosives are initiated by a detonator. Secondary explosives are used for blasting and to obtain fragmenting and accelerating effects in many industrial and military applications (Goulart et al., 2022).

According to Goulart et al. (2022) various types of explosives are defined as follows:

- Civilian explosives are explosives that are commercially produced for non-military use. Examples are dynamites, ANFO, and emulsion explosives (Goulart et al., 2022);
- Blasting explosives is a term used for explosives in civil use, e.g. in quarrying, road construction, and demolition (Goulart et al 2022);
- Emulsion explosives are explosives in the form of emulsion. They are relatively safe to use and hard to initiate. The primary use for emulsion explosives is for civilian use in the mining industry and during road and tunnel construction work (Goulart et al 2022);
- Energetic materials are defined as a class of compounds, substances and formulations containing a high amount of stored chemical energy, which may be manipulated to be released in a controlled manner. This would include, but is not limited to, materials such as explosives, propellants, pyrotechnics, and their ingredients; and

Binary explosives are two-component explosives which contain two safe-to-handle compounds. The final explosive is prepared by mixing both compounds before use. Home-made explosives (HMEs) are commonly encountered in improvised explosive devices (IED). There are two main categories that prepare and/or use HMEs; HMEs can be made from many different precursors, and some of them may be innocuous in themselves and easily accessible. The threat of improvised explosive device attacks is a global problem. Cheap and relatively easy to construct, IEDs can be made anywhere from a wide range of materials. Categorisation of the harm from the explosive device can be determined through its velocity (high/low). The lack of proper stockpile security for military and commercial explosives – making them susceptible to diversion into illicit hands – also presents a significant security risk (UNODA, 2014).

Metrics and numeric limits

The charge mass for various types of explosives can be expressed in TNT-equivalent (kg). TNT equivalent refers to the amount of energy released by an explosion, measured in terms of the energy released by a specific amount of TNT.

Key relevant UN convention /multilateral treaty

Convention on Certain Conventional Weapons, Amended Protocol II (United Nations, 2008).
In 2015, Afghanistan took the lead within the United Nations General Assembly to develop a resolution focused on the need for an effective global, comprehensive, coordinated approach to counter the proliferation of IEDs in settings of violent extremism and instability. The resolution (70/46), adopted by consensus, included a call for the consistent collection of data, awareness raising, options for the regulation of components, international technical assistance and cooperation, and victim assistance (UNODA, 2014).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Hazard drivers associated with explosive agents include inappropriate handling, unsafe storage, and unsafe transport (HSE, 2002).

Many types of explosive weapons exist and are currently in use. These include air-delivered bombs, artillery projectiles, missiles and rockets, mortar bombs, and improvised explosive devices (IEDs). Some are launched from the air and others are surface launched.

Preliminary – Corrections Pending

Whilst different technical features dictate their accuracy of delivery and explosive effect, these weapons generally create a zone of blast and fragmentation with the potential to kill, injure or damage anyone or anything within that zone. This makes their use in populated areas – such as towns, cities, markets and camps for refugees and displaced persons or other concentrations of civilians – particularly problematic. The problems increase further if the effects of the weapon extend across a wide area either because of the scale of blast that they produce; their inaccuracy; the use of multiple munitions across an area; or a combination thereof (UNOCHA 2017).

Ammonium nitrate is an explosive and its inadequate storage has caused several explosions (Al-Hajj et al., 2021).

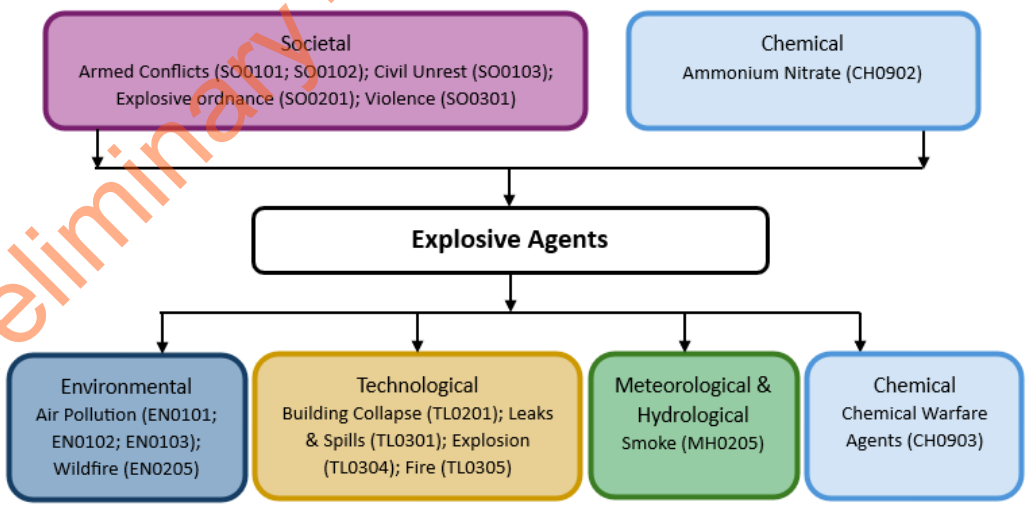
Impacts: The hazard area needs to be assessed whenever an explosive (or potentially explosive) device is found or used. The hazard area depends on the amount of explosive. The hazard area needs to take into account the pure blast effects (shock wave) as well as the effects of a fragmenting charge (shrapnel), fragmenting source, the fireball, the crater volume, and the cratering ejecta. The hazard area is larger for a larger amount of explosive as well as for a fragmenting charge.

Injury depends on the specific location of an explosion can intensify its severity, potentially causing more harm, but injuries from explosions are usually classified as follows:

- Primary: caused by a sudden increase in pressure after an explosion, affecting air-containing organs, such as the lung, ear, eye, etc.
- Secondary: result from bomb fragments and debris being energized by the explosion. These have varying levels of lethality; larger fragments can transfer more energy, increasing the harm caused.
- Tertiary: caused when the casualty is thrown by the explosion and collides with nearby objects. They can have both local and global effects; local deformation of the floor of a protective structure for example, or global acceleration of the structure itself with the casualty inside it.
- Quaternary: related to the thermal effects of the blast, toxic effects, and any risks resulting from the incident, such as drowning (vehicle rollover into river) or freezing (shelter destruction) (UK Parliament POSTNOTE 2011).

The indiscriminate nature of explosions means that both children and women, including pregnant women, can be injured. Disruption of the placenta and foetal skull fractures can occur as a result of these events in pregnant women. Children suffer a greater proportion of injuries to the head due to its larger size compared with the rest of the body (UK Parliament POSTNOTE 2011).

Multi-hazard Context: The figure below summarises common interactions between explosive agents and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: Monitoring and sharing early warning systems in the European Union (EU) is part of the EU action plan on enhancing the security of explosives. The EU EWS is used to exchange information between authorities in different member States, on, for example: immediate threats, theft of explosives, theft of detonators, discovery of new modus operandi, etc. (Goulart et al., 2022).

Risk Management: Training on understanding the phenomenon of explosions including their consequences, the prevention techniques available, and the regulatory requirements for a safe and compliant working environment. is provided by many organisations.

Mechanisms exist in many places and as an example the European Explosive Ordnance Disposal Network (EEODN) is a network

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of law enforcement specialists in explosives and CBRN from the competent authorities of EU MS. Created by EUROPOL in 2008 in order to facilitate cooperation, to share technical and case related information among EU explosives and CBRN specialists and to organise joint trainings and exercises.

As examples of risk management Goulart et al. (2022) describe explosives detection systems within aviation security today normally meaning X-ray screening equipment for hold baggage (also called check-in baggage) (Goulart et al., 2022).

Explosive Detection Dogs (EDD) are dogs trained for the detection of explosives and are used as a mobile detectors with a unique capacity to find the source, thanks to their strong sensitivity to odours (1,000-10,000,000 times higher than that of human being, explained by the presence of 300 million olfactory receptors that line their nostrils, against 6 million in human being.) However, canine detection has limitations in terms of not being able to communicate an identification of the substance detected. EDDs are allowed as a screening method for screening persons, cabin baggage and hold baggage and cargo in civil aviation. They are also frequently used in infrastructure protection (Goulart et al., 2022). Additionally, strengthening vigilance and national controls: IEDs are often made with military- or commercially-sourced explosives. The UN General Assembly resolution calls for measures to be put in place to establish tighter controls over materials or components used for making IEDs. These controls could encompass national ammunition stockpiles and industrially produced detonators, detonating cords and industrially produced explosives, such as for mining. Relevant industries and corporations could also be encouraged to engage in the regulation of precursor and prefabricated components (UNODA, 2014). Enhancing information sharing: owing to the ad-hoc design of IEDs, there is an overriding need for States to share information on the composition and production methods of captured IEDs, including after IED attacks. The resolution underlines this necessity. Effective information sharing on IED designs and components between Member States has the potential to shorten the learning curve that military and security forces have to go through in order to identify and develop effective counter-measures. Also, civilians will be protected better when effective information sharing on new IED designs leads to quicker neutralisation (UNODA, 2014).

The Secretary-General of the United Nations has highlighted the indiscriminate and severe humanitarian impact of the use of explosive weapons in populated areas since 2009. He has consistently used his reports to the Security Council on the protection of civilians in armed conflict to bring attention to the devastating effects of the use of explosive weapons in populated areas on civilians; and continues to appeal to parties to armed conflict and States to avoid the use of explosive weapons in populated areas, to work to remove conflict from urban areas altogether and to avoid locating military objectives within or near densely populated areas (UNODA no date).

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Coordinating agency or organisation

Not identified.

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TL0307 / TECHNOLOGICAL / Industrial Failure

Mining Hazards

Definition

Mining hazards may cause major environmental and health impacts such as pollution of water bodies, degradation of forest resources, depletion of soil nutrients, destruction of wildlife habitat, and threats to human health. (adapted from UNDP and UN Environment, 2018).

Reference

UNDP and UN Environment, 2018. Managing Mining for Sustainable Development: A sourcebook. United Nations Development Programme (UNDP). www.undp.org/content/undp/en/home/librarypage/poverty-reduction/Managing-Mining-for-SD.html.Accessed 6 February 2025

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Annotations

Synonyms

Mining catastrophes, mining disasters.

Additional scientific description

Over recent decades, mining has generated considerable wealth, reduced poverty in developing countries, and improved quality of life through the provision of natural resources. Although mining has considerable benefits, this industry can have harmful impacts on people, society, and the environment (Donelly, 2018). The most common mining hazards include but are not limited to ground collapse, subsidence, fault reactivation and fissures, mine water rebound, acid mine water drainage, mine gas emissions, and combustion. Other notable hazards are mining-induced landslides, mining-induced seismicity, waste, dereliction, and contamination. Although potentially foreseeable, mining hazards cannot necessarily be forecast or predicted in terms of their timing, location, duration, magnitude, and extent. Mining hazards can occur in isolation or as groups of hazards occurring simultaneously (Donelly, 2018).

Artisanal and small-scale mining (ASM) has experienced substantial growth in recent years, largely due to the increasing value of mineral prices and additional sources of income, particularly in Africa and Latin America. Despite being low in productivity, ASM is an important source of minerals and metals and accounts for approximately 20% of the global gold supply and 20% of the global diamond supply. In 2017, 40.5 million people were estimated to have been involved in this sector. The most recent estimates are for about 9 million ASM operators in Africa and about 54 million people whose livelihoods depend on the sector (IGF, 2017). However, The Africa Minerals Development Centre considers this a 'conservative estimate', citing an important lack of data on ASM, as the activity is often informal and mostly operates illegally in several African countries. The Latin America ASM sector has strict regulations on informal operators and the use of certain substances but has limited capacity to implement these regulations. It is particularly difficult to control informal mining where there are large numbers of miners, such as in Colombia, where about 87% of 4134 Colombian gold mining operations are illegal and 95% of all the gold mines have no environmental permit (IGF, 2017). Perceptions of ASM activity vary from country to country. Stakeholders often tend to vilify artisanal and small-scale mining because of its informal nature and hazardous characteristics, with significant health and safety risks as well as susceptibility to social conflict and human rights violations (Barreto, 2011).

Mining hazards may occur during the exploitation of the mine and differ depending on what is mined and how. For example, underground coal mining may cause subsidence, landslides, fissures, and even hazard chains, seriously damaging the ecological environment (Ma et al., 2022). Gold mining often involves the use of chemicals dangerous for the health of the workers, their community and the surrounding environment, for example through the migration of pollutants into the air, the soil and the water (Liu et al., 2021; Wongsasuluk et al., 2021; Gerson et al., 2022).

During mining, the use of hazardous substances in mining puts the health of miners and their communities at risk – they are

exposed, for example, to mercury, zinc vapour, cyanide, or other acids. This is a particular concern in artisanal gold mining, where mercury is frequently deployed and cyanide use is growing. Other health concerns include inhaling dust and fine particles from blasting and drilling processes causing respiratory diseases such as silicosis or pneumoconiosis in men and women, and in the children who often accompany their parents a lack of ear protection to filter noise from equipment such as drills or crushers can cause temporary or permanent hearing loss and speech interference (ILO, 2014).

Concrete actions started in 2018 with a focus on formalisation, establishing gold-buying schemes, capacity building at the national level on mercury-free technologies, awareness raising and knowledge sharing (UNEP, 2019).

Metrics and numeric limits

Not available.

Key relevant UN convention / multilateral treaty

There is no treaty on environmental pollution from mining activities, but several conventions regulate work in mines:

- Occupational safety and health in the mining (coal and other mining) sector (ILO, 2014).
- Hours of Work (Coal Mines) Convention (No. 31) in 1931 to the Safety and Health in Mines Convention (No. 176), which was adopted in 1995 (ILO, 2014).

The ILO's International Classification of Radiographs of Pneumoconioses and Guidelines (OSH 22) is an internationally recognised tool for recording systematically radiographic abnormalities in the chest provoked by the inhalation of dusts (ILO, 2014). The ILO has created the following labour standards and codes of practice relevant to mining hazards:

ILO International labour standards

- Occupational Safety and Health Convention (No. C155) and Recommendation (No. R164), 1981
- Promotional Framework for Occupational Safety and Health Convention (No. C187) and Recommendation (No. R197), 2006
- Occupational Health Services Convention (No. C161) and Recommendation (No. R171), 1985
- Safety and Health in Mines Convention (No. C176) and Recommendation (No. R183), 1995
- C124 - Medical Examination of Young Persons (Underground Work) Convention, 1965
- R125 - Conditions of Employment of Young Persons (Underground Work) Recommendation, 1965 (No. 125)

ILO Codes of practice

- 2006 - Safety and health in underground coal mines
- 1991 - Safety and health in opencast mines
- 1986 - Safety and health in coal mines
- 1974 - Prevention of accidents due to explosions underground in coal mines
- 1965 - Guide to the prevention and suppression of dust in mining, tunnelling and quarrying
- 1959 - Prevention of accidents due to electricity underground in coal mines
- 1959 - Prevention of accidents due to fires underground in coal mines
- 1949 - Model code of safety regulations for underground work in coal mines

Examples of hazard drivers, impacts and risk management

Hazard Drivers: The major multi-hazards related to mines include ground collapse and subsidence, sinkholes, mine flooding, water pollution, toxic gas leaks, and explosion risks. Natural hazards such as earthquakes (Senses & Kumral, 2023) and floods (Mason et al., 2013) can exacerbate mining hazards. These multi-hazards can occur sequentially or simultaneously, further amplifying the risks (Wu et al., 2022).

Lack of governance and inappropriate practices may increase the risk of accidents, in particular, at artisanal mining sites (Adu-Baffour et al., 2021).

Impacts: Mining activities release dust in the surrounding environment, with impacts on the health of surrounding communities (Entwistle et al., 2019) and the environment (Yu & Zahidi, 2023). Underground coal mining releases potentially harmful gases during accidents (Zykov & Filatov, 2018).

Occupational hazards are a major consequence of mining activities. Although only accounting for 1% of the global workforce, mining is responsible for about 8% of fatal accidents at work. No reliable data exist on injuries, but they are significant, as is the number of workers affected by such disabling occupational diseases as pneumoconiosis, hearing loss and the effects of vibration (ILO, 2015). Mineworkers face a constantly changing combination of workplace circumstances. Some work in an atmosphere without natural light or ventilation, creating voids in the earth by removing material and trying to ensure that there will be no immediate reaction from the surrounding strata. Despite the efforts in many countries, injury and disease among the world's

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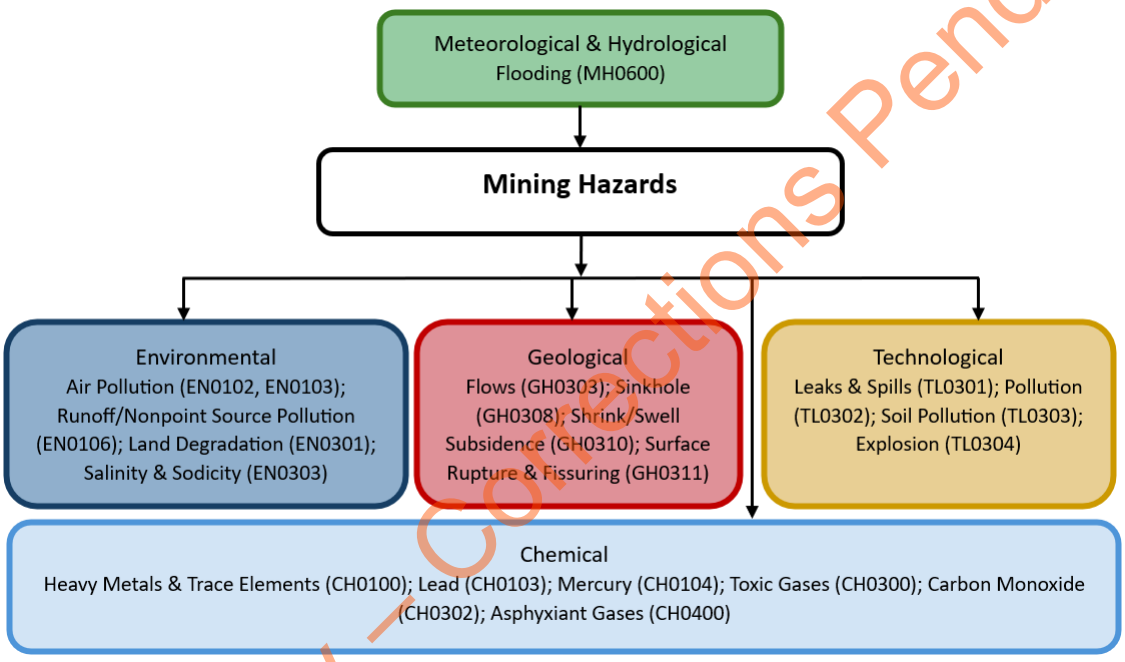
mineworkers means that, in most countries, mining remains the most hazardous occupation when the number of people exposed to risk is taken into account (ILO, 2015). In some countries, many more people are employed in small-scale, often informal, mining than in the formal mining sector. Many of these jobs are precarious and far from conforming to international and national labour standards. Accident rates in small-scale mines are routinely six or seven times higher than in larger operations, even in industrialised countries. A special problem is the employment of children (IGF, 2017).

Once the activities end and the mine is abandoned, the release of pollutants may continue for several years (Demkova et al., 2017). Abandoned underground mines (for coal or stones); may lead to collapse, manifesting at surface from shallow depressions to sinkhole-like structures. This type of damage can lead to financial loss for anyone involved in the ownership or management of property in former mining areas, including householders, developers and local government (British Geological Survey, 2025).

Multi-hazard Context: The figure below summarises common interactions between mining hazards and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring mining hazards. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	• Environmental agencies, Hydrological agencies • Geological survey institutions • Mining Companies, health agencies for occupational hazards.
How is the Hazard Observed/Monitored/Forecast?	• Remote sensing (Yu & Zahidi, 2023) • Various sensors and monitoring technologies to identify, in real-time, hazards such as gas concentration, ground stability, and temperature • Literature review and mapping (British Geological Survey, 2025) • The Mine Safety and Health Administration (MSHA) in the United States operates a Proximity Detection/Collision Warning System. This system, developed in collaboration with the mining industry, incorporates life-saving technology that can halt machine movement or send warning signals to operators when a person or object is detected in the machine's path (MSHA, no date). • Early warning method for gas explosion hazards by integrating an intelligent mining system with multivariate data analysis. This system utilises real-time data from mine safety monitoring, personnel tracking, and video surveillance. A model built using the Random Forest classification algorithm demonstrated 100% accuracy in predicting gas explosion risks (Li et al, 2023), a comprehensive early warning system for rock collapse hazards using monitoring technologies such as micro-seismic, acoustic emission, and electromagnetic radiation (Song et al, 2024).

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Risk Management: Risk generated by extreme events also needs to be incorporated in planning and management into pre-development, development and construction, mining and processing operations and post-mining phases. Whilst mining and mineral professionals have experience with risk management and managing workplace health and safety, changes to patterns of extreme weather events and future climate impacts are unpredictable. Responding to these challenges requires planning and preparation for events that many people have never experienced before.

To prevent mining hazards from occurring, monitoring and site inspections are recommended prior to, during, immediately after and long after mineral production ceases and a mine is abandoned (Donelly, 2018). Governance needs to be improved and regulations enforced. The Global Environment Facility has developed the Global Opportunities for Long-term Development of ASGM Sector (GEF GOLD) which is an important funding body for projects on ASM and hazardous substances. In 2016, the Global Opportunities for Long-term Development (GEF GOLD) was launched to support the phasing out of mercury use in artisanal and small-scale gold mining and reduce environmental health and safety risks in the sector. The United Nations Industrial Development Organization (UNIDO) is one of the main organisations in charge of implementing the project which is targeted at Burkina Faso, Colombia, Guyana, Indonesia, Kenya, Mongolia, Peru and the Philippines (GEF, 2017).

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Coordinating agency or organisation

Not identified.

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TL0308 / TECHNOLOGICAL / Industrial Failure

Safety Hazards Associated with Oil and Gas Extraction

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Definition

Oil and gas extraction and associated servicing activities involve many types of equipment and materials. Identifying and controlling hazards is critical to preventing injuries and deaths (US Department of Labor, no date).

Alternative definition: For the purpose of the C155 - Occupational Safety and Health Convention, 1981 (No. 155) (ILO, 1981):

a) the term 'branches of economic activity' covers all branches in which workers are employed, including the public service.
b) the term 'workers' covers all employed persons, including public employees.
c) the term 'workplace' covers all places where workers need to be or to go by reason of their work and which are under the direct or indirect control of the employer.
d) the term 'regulations' covers all provisions given force of law by the competent authority or authorities.
e) the term 'health', in relation to work, indicates not merely the absence of disease or infirmity; it also includes the physical and mental elements affecting health which are directly related to safety and hygiene at work.

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Annotations

Synonyms

Petroleum industry hazards, oilfield accidents, gas extraction risks

Additional scientific description

The oil and gas industry will continue to play a vital role in providing affordable, reliable, and versatile energy solutions to support a growing global population. According to the International Energy Agency (IEA), in 2024, oil and gas together accounted for over 50% of global energy demand. The challenge lies in balancing the reduction of emissions to address climate change while ensuring sufficient energy supply to support also meeting global economic development (IAEA, 2019).

Oil and gas extraction encompasses activities such as exploration, drilling, production, and construction. It also involves the transport of materials, planning, building, equipping and maintaining refineries and facilitating the delivery of energy products to end users. (ILO, 2010).

Oil and gas extraction poses significant risks, including damage to property, environmental degradation, and threats to human safety. These risks are heightened if activities are not adequately controlled, monitored or regulated. (Rodhi et al., 2018). Safety hazards associated with oil and gas extraction activities include but are not limited to (US Department of Labor, no date):

- *Vehicle collision:* workers and equipment are required to be transported to and from sites, which are often located in remote areas. Highway vehicle crashes are the leading cause of oil and gas extraction worker fatalities. In the United States, roughly four out of every ten workers on the job in this industry are killed as a result of a highway vehicle incident.
- *Struck-by/ caught-in/caught-between:* workers might be exposed to struck-by/caught-in/caught-between hazards from multiple sources such as moving vehicles or equipment, falling equipment, and high-pressure lines. In the United States, this hazard is responsible for three in five on-site fatalities in the oil and gas industry.
- *Explosions and fires*: flammable gases such as well gases, vapours, and hydrogen sulphide, can be released from wells, trucks, production equipment or surface equipment. Ignition sources can include static, electrical energy sources, open flames, lightning, cutting and welding tools, hot surfaces, and frictional heat. Workers in the oil and gas industry face these risks, particularly the risk of fire and explosion due to the ignition of flammable vapours or gases.
- *Falls:* can be a direct result of workers being required to access platforms located high above ground.
- *Confined spaces: w*orkers are often required to enter confined spaces such as petroleum and storage tanks, mud pits, reserve pits and other excavated areas. Safety hazards associated with confined space include ignition of flammable vapours or gases. Health hazards include asphyxiation and exposure to harmful chemicals. Confined spaces that contain or have the potential to contain a serious atmospheric hazard must be classified as permit-required confined spaces, tested prior to entry, and continuously monitored.
- *Ergonomic hazards:* oil and gas workers might be exposed to ergonomics-related injury risks such as lifting heavy items, bending, reaching overhead, pushing and pulling heavy workloads and performing the same tasks repetitively. Risk factors can be minimised or eliminated through interventions such as pre-task planning, using the right tools and education and awareness of potential hazards.
- *High-pressure line and equipment:* workers in this industry may be exposed to hazards from compressed gases or from high-pressure lines. This can be a result of internal erosion of lines which might result in leaks or line bursts.
- *Electrical and other hazardous energy*: industry workers may be exposed to uncontrolled electrical, mechanical, hydraulic, or other sources of hazardous energy if equipment is not designed, installed, and maintained properly.
- *Machine hazards:* oil and gas extraction workers may be exposed to a wide variety of rotating wellhead equipment including top drives and kelly drives, pumps, compressors, catheads, hoist blocks, belt wheels and conveyors, and might be injured if they are struck by or caught between unguarded machines.
- *Planning and prevention:* many countries within the industry use job safety analysis (ISA) processes to identify hazards and find solutions to reduce incidents that could lead to injury or fatalities.

Metrics and numeric limits

The International Association of Oil & Gas Producers (IOGP) recent 'Safety Data Report' concluded that fewer fatalities and injuries occurred in 2023 compared to the year prior (IOGP, 2024) and overall, a 36% reduction in the Fatal Accident Rate. In 2023, the industry experienced 27 fatalities in 17 separate incidents across 3.3 billion work hours. The largest proportion of fatalities was attributed to 'assault or violent act'. Data reported by IOGP members also recorded a decline in the number of injuries. In 2023, there were 0.84 injuries per million hours worked, 7% lower than in 2022 (IOGP, 2024).

Preliminary – Corrections Pending

Key relevant UN convention / multilateral treaty

ILO International labour standards:

C155 - Occupational Safety and Health Convention, 1981 (No. 155)

R164 - Occupational Safety and Health Recommendation, 1981 (No. 164)

C187 - Promotional Framework for Occupational Safety and Health Convention, 2006 (No. 187)

R197 - Promotional Framework for Occupational Safety and Health Recommendation, 2006 (No. 197)

C161 - Occupational Health Services Convention, 1985 (No. 161)

R171 - Occupational Health Services Recommendation, 1985 (No. 171)

ILO Codes of practice:

- Safety and health in the construction of fixed offshore installations in the petroleum industry
- Occupational safety and health in the oil and gas production and oil refining sector (ILO, no date).

Global Political Commitments: Initiatives, Declarations, Action Plans, Programmes as listed by the Global Marine Oil Pollution Information Gateway (no date):

Global Political Commitments: Initiatives, Declarations, Action Plans, Programmes

Agenda 21. World Summit on Sustainable Development (WSSD 2002).

Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA).

International Conventions:

Convention on the Law of the Sea (UNCLOS).

MARPOL 73/78: International Convention for the Prevention of Pollution from Shipping. Pollution Casualties. have been amended twice in 1991 and 1996. The IMO provides the secretariat for the Convention.

London Convention: Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter.

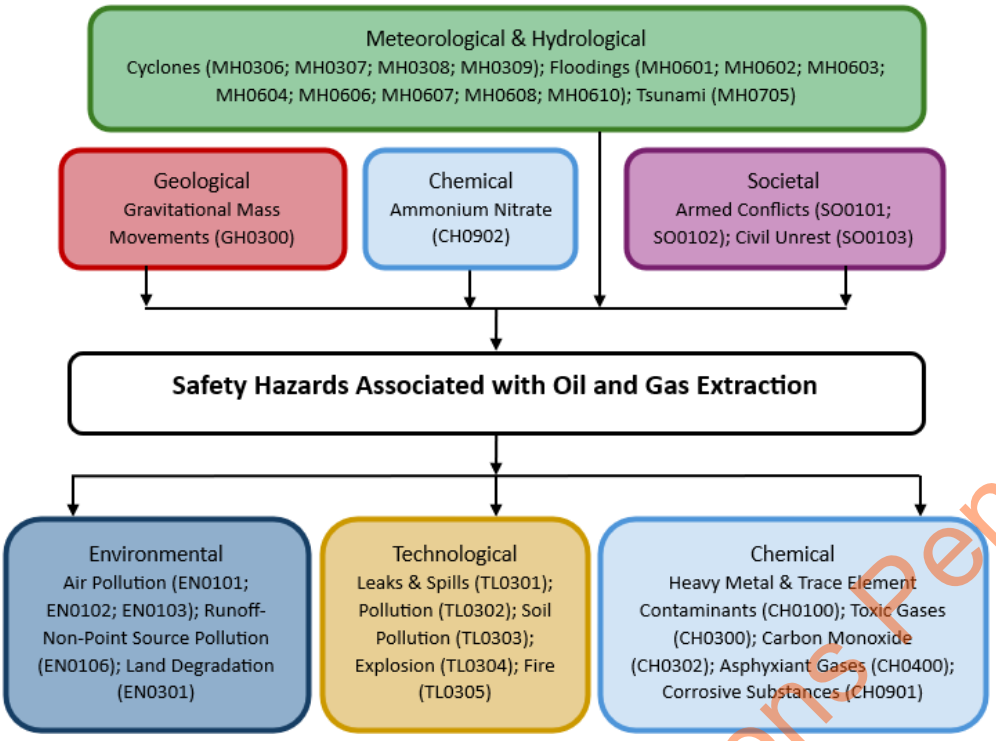
Examples of hazard drivers, impacts and risk management

Hazard Drivers: Installations for oil and gas extraction may be affected by different hazards, including earthquakes, landslides and floods. Some of these installations may also be targeted during conflicts.

Impacts: Accidents on oil and gas extraction sites may lead to explosions, fires and the release of hazardous products such as asphyxiant gases, toxic gases, carbon monoxide and strong acids and strong bases. Environment degradation may also result from these activities.

Multi-hazard Context: The figure below summarises common interactions between safety hazards associated with oil & gas extraction activities and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

Preliminary – Corrections Pending



Monitoring: Increasingly remote monitoring is being introduced in the oil and gas industries and offers real-time visibility and early identification of problems, facilitating response.

Risk Management: IOGP serves as a global partner for improving safety and overall oil and gas industry performance. IOGP also acts as a global forum within which members can identify and share best practices to achieve improvements in health, safety, environment, security, social responsibility, engineering and operations within the sector. IOGP works to improve the industry and make a positive contribution to society through the publication of reports, guidelines and recommended practices.

Other systems for risk management include real-time safety dashboards and predictive maintenance.

Leading oil and gas companies have increased efforts towards adopting a risk-based approach, through enhancing risk management capability such as the management of health, safety, and environment (HSE) risks by implementing the risk management framework 130 31000:2009 to achieve sustainable development (Rodhi et al., 2018).

Preliminary – Corrections Pending

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Coordination agency or organisation

Not identified.

Preliminary – Corrections Pending

TL0309 / TECHNOLOGICAL / Industrial Failure

Natech

Definition

Natural hazard triggered technological accident (Showalter et al., 1994).

Reference

Showalter, P.S. and M.F. Myers, 1994. Natural disasters in the United States as release agents of oil, chemical, or radiological materials between 1980-1989: analysis and recommendations. Risk Analysis, 14:169-182. DOI: https://onlinelibrary.wiley.com/doi/epdf/10.1111/j.1539-6924.1994.tb00042.x Accessed 20 May 2025

Annotations

Synonyms

Natech accident, Secondary technological hazard. Technological disaster triggered by natural hazards;

Additional scientific description

Natural hazards can trigger fires, explosions, and toxic or radioactive releases at hazardous installations and other infra-structures that process, store, or transport dangerous substances (Krausmann et al., 2017). These technological 'secondary effects' caused by natural hazards are also called 'Natech' accidents. They are a returning but often overlooked feature in many natural-hazard situations and have repeatedly had significant and long-term social, environmental, and economic impacts. In the immediate aftermath of a natural disaster (UNDRR, 2019), Natech accidents add significantly to the burden of the population already struggling to cope with the effects of the triggering natural event (Krausmann et al., 2019).

Natech event consequences can range from health impacts and environmental degradation (e.g. during the 2008 Wenchuan earthquake) to major economic losses at local or regional levels due to damage to assets and business interruption (e.g. due to the 2011 Thai floods). In some cases, ripple effects across sectors can reach global proportions, resulting in a shortage of raw materials and finished products (as was the case following the 2011 Great East Japan earthquake and tsunami) and price hikes (e.g. the impact of Hurricanes Katrina and Rita on the offshore infrastructure in the Gulf of Mexico) (UNDRR, 2019).

Metrics and numeric limits

In addition to country initiatives to address Natech hazards, several international bodies have started to address Natech hazards and risks. For example,

- Organisation for Economic Co-operation and Development (OECD) issued a Natech addendum to its 2nd edition of the Guiding Principles for Chemical Accident Prevention, Preparedness and Response (OECD, 2015). The addendum consists of a number of modifications to the Guiding Principles and the addition of a new chapter providing more detailed guidance on Natech prevention, preparedness and response. In the recent 3rd edition of the Guiding Principles, Natech risk considerations have been incorporated directly in the guidance text (OECD, 2023).
- World Health Organization, recognising the potential for severe acute and chronic health impacts from Natech accidents issued information for public health authorities in the wake of chemical releases caused by natural events, focusing on earthquakes, floods and cyclones. It aims to provide brief information to planners in the health sector and to public health authorities who wish to learn more about chemical releases resulting from natural events (WHO, 2018).
- United Nations Office for Disaster Risk Reduction (UNDRR) has gathered a team of experts who prepared Words into Action Guidelines for National Disaster Risk Assessment and for Man-made/Technological Hazards, both of which contain chapters that discuss actions and guidance for Natech risk reduction (UNDRR, 2020).

Preliminary – Corrections Pending

Recently, work on developing metrics to measure the performance of Natech risk management has been made by the European Commission's Joint Research Centre (JRC) (Krausmann et al., 2019), and a framework for a performance rating system has been proposed by researchers at Kyoto University in Japan (Suarez-Paba, 2019). The JRC has also released technical guidance for Natech risk management for operators of hazardous industrial sites and for national authorities (Necci and Krausmann, 2022) and with OECD and UNECE launched joint guidance on Natech risk management for senior leaders in industry and public authorities (OECD/European Union 2024)

Relevant UN convention / multilateral treaty

UNECE Convention on the Transboundary Effects of Industrial Accidents (UNECE, 2017).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Natural hazards can cause multiple and simultaneous releases of hazardous materials over extended areas, damage or destroy safety barriers and systems, and disrupt lifelines needed for accident prevention and consequence mitigation. These are also the ingredients of cascading disasters. Emergency responders are usually not prepared for or do not have the necessary resources to combat multiple release events at the same time (Girgin et al., 2019).

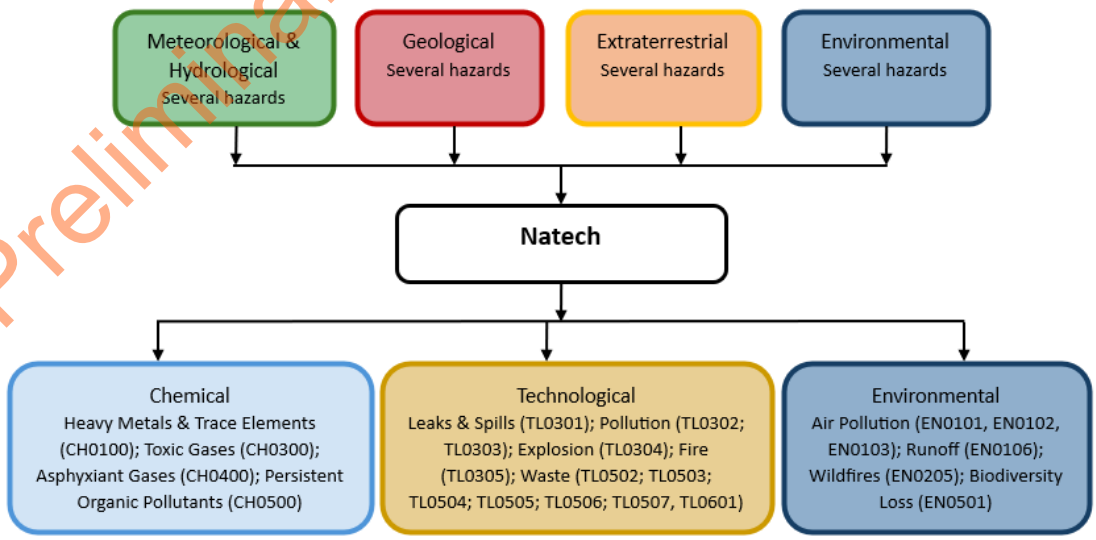
Past events have shown that compound events (e.g., rain on snow cover, leading to increasing snowmelt) or cascading effects (e.g., an earthquake that triggers hazardous materials releases which are then dispersed by a tsunami that follows the earthquake) can increase Natech risk. In case of hydro-meteorological hazards, climate change also amplifies Natech risk by directly impacting the frequency/severity of the triggering natural hazard.

Impacts: Community encroachment on natural-hazard areas, climate change, rapid demographic changes and urbanisation all increase the exposure (and vulnerability) of the population to Natech hazards (Krausmann et al., 2017). Identification of Natech hazards is not always easy as information on technological hazards is often considered confidential and is closely held by industry unless notification and reporting obligations exist.

In addition to acute effects, chronic environmental and health impacts may arise from slow-release Natech events, particularly in groundwater and soil systems (Krausmann et al., 2019; US EPA, 2024).

Indirect effects may include biodiversity loss from persistent contamination or increased cancer rates due to chronic exposure to pollutants released in Natech events.

Multi-hazard Context: The figure below summarises common interactions between Natech and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: Not Applicable

Preliminary – Corrections Pending

Risk Management: The risk management of an industrial installation is usually viewed in isolation from its surroundings and does not take account of the potential interactions with other industry, lifelines and nearby communities to capture the potential for cascading events and the impact on industry resilience, continuity, and recovery (Krausmann et al., 2017). A call for integrated risk governance of Natech hazards has been made, which requires bringing together industry, government agencies overseeing regulatory frameworks, public health and environment authorities, city planners, emergency responders and natural hazard experts, together with potentially affected communities, in order to promote resilient territories (UNDRR, 2017).

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Preliminary – Corrections Pending

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Coordinating agency or organisation

European Commission Joint Research Centre.

Preliminary – Corrections Pending

TL0401 / TECHNOLOGICAL / Transportation

Air Transportation Accident

Definition

An air transportation accident is defined as an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, in which one of the following applies: a person is fatally or seriously injured, the aircraft sustains damage or structural failure, and the aircraft is missing or is completely inaccessible (United Nations, European Union, the International Transport Forum at the OECD, 2019:119).

Reference

United Nations, European Union and the International Transport Forum at the OECD (2019). Glossary for transport statistics. 5th Edition. www.unece.org/fileadmin/DAM/trans/main/wp6/pdfdocs/Glossary_for_Transport_Statistics_EN.pdf Accessed 27 January 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Aviation accident. Aircraft incident. Plane crash. Spanish: accidente aéreo. French: accident d'aviation.

Additional scientific description

Additional information on air transportation accidents from the Glossary for Transport Statistics (United Nations, European Union and the International Transport Forum at the OECD, 2019) is as follows:

- A person is fatally or seriously injured where this is as a result of being in the aircraft, or direct contact with any part of the air-craft, including parts which have become detached from the aircraft, or direct exposure to jet blast, except when the injuries are from natural causes, self-inflicted or inflicted by other persons, or when the injuries are to stowaways hiding outside the areas normally available to the passengers and crew.
- The aircraft sustains damage or structural failure where this adversely affects the structural strength, performance or flight characteristics of the aircraft, and would normally require major repair or replacement of the affected component (except for engine failure or damage when the damage is limited to the engine, its cowlings or accessories; or for damage limited to propellers, wing tips, antennas, tyres, brakes, fairings, small dents or puncture holes in the aircraft skin).
- The aircraft is missing or is completely inaccessible - an aircraft is considered to be missing when the official search has been terminated, and the wreckage has not been located.

Metrics and numeric limits

The International Civil Aviation Organization (ICAO) is a UN agency, established in 1944 to manage the administration

and governance of the Convention on International Civil Aviation (Chicago Convention). ICAO hosts an application which provides occurrence data as well as accident and fatality statistics up to 2019 (ICAO, 2019; ICAO, 2024).

Statistically agreed metrics for air transportation accidents (United Nations, European Union and the International Transport Forum at the OECD, 2019) are as follows:

- Fatal injury: an injury resulting in death within 30 days of the date of the accident.
- Non-fatal injury: an injury, other than a fatal injury, which is sustained by a person in an accident.

Serious injury: a non-fatal injury which is sustained by a person in an accident and which requires hospitalisation for more than 48 hours, commencing within seven days from the date the injury was received; or results in a fracture of any bone (except simple fractures of fingers, toes, or nose); or involves lacerations which cause severe haemorrhage, nerve, muscle or tendon damage; or involves injury to any internal organ; or involves second or third-degree burns, or any burns affecting more than 5% of the body surface; or Involves verified exposure to infectious substances or injurious radiation.

- Slight injury: a non-fatal injury, other than a serious injury, which is sustained by a person in an accident.

Key relevant UN convention / multilateral treaty

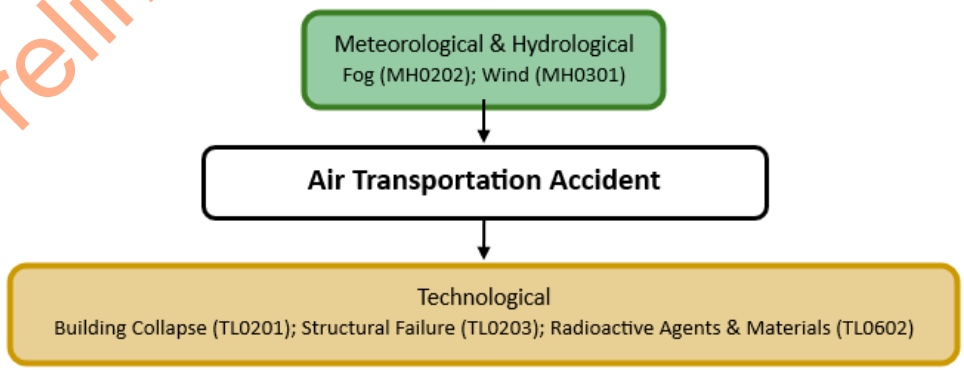
Convention for the Unification of Certain Rules for International Carriage by Air, also known as the Montreal Convention, adopted in 1999 by ICAO member states (IATA, 1999; UN Treaty Collection, 1999).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: The ICAO lists the drivers of air accidents as being runway safety-related events, loss of control in flight, controlled flight into terrain, and malicious events (ICAO, 2019). According to statistics, up to 80% of all aviation accidents are attributed to human error. The most critical periods are during take-off, landing, and the moments surrounding these events. Pilot errors account for 53% of aviation accidents, followed by mechanical failures (21%) and weather conditions (11%) (Gunturkun, 2023). Airport proximity to dense urban areas and inadequate land use planning around airports can exacerbate risks related to aviation accidents, especially during take-off and landing phases which account for the majority of accidents.

Impacts: From 2022 to 2023, there was a 3.1% increase in the total number of accidents, as reported by States, noting that flight departures increased by around 13%during the same period of time. The global accident rate of 1.87 accidents per million departures in 2023 decreased by 17.9%from the 2022 rate of 2.05 accidents per million departures (ICAO, 2024).

Multi-hazard Context: The figure below summarises common interactions between air transportation accidents and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Air transportation is affected by cross-hazard interactions, such as volcanic ash clouds, for example, from the Eyjafjallajökull eruption in 2010, which caused airspace closures (NCAS, no date). In addition, during the COVID-19 pandemic, flights were reduced by 43% in 2020 compared to 2019 (Bielecki et al, 2020)

Preliminary – Corrections Pending

Monitoring: ICAO's Aviation Weather Centers (AWCs) are facilities that provide aviation weather services, including forecasts and observations, to support safe and efficient air travel. The Federal Aviation Administration (FAA) Weather Camera Program improves aviation safety and efficiency by providing pilots with near real-time visual weather data (FAA, 2025). NASA's Aviation Safety Program focuses on developing technologies related to weather information to reduce aviation accidents. The weather information system consists of three key elements: Weather Products, Data Distribution, and User Interface. High-precision weather information is generated using onboard sensors, ground-based systems, and satellite technologies. In collaboration with the FAA, the program aims to deliver weather observation data within 5 minutes and provide analysis and forecasts within 15 minutes through data links. Additionally, advanced weather radar technology is utilized to identify turbulence in the aircraft's flight path. In this system, atmospheric data is analysed to predict how the aircraft may react to specific conditions. The system presents a real-time assessment of risk levels to enhance situational awareness for pilots (Stough, 2000).

GIS-based monitoring systems can integrate multiple data sources to evaluate spatial risk patterns around airports. Studies, such as Septanaya et al. (2024), have demonstrated that integrating spatial planning with aviation safety monitoring can improve risk assessment and management.

Risk Management: The ICAO describes the overall purpose of their Global Aviation Safety Plan (GASP) as being to guide the harmonized development of regional and state safety planning, supported by regional safety activities coordinated by the regional aviation safety groups (ICAO, 2022).

The ICAO is coordinating an international effort to bring together expertise from such organizations as the World Health Organization (WHO), the International Air Transport Association (IATA), the Airports Council International (ACI) and other partners to assist in preparedness planning, not only for pandemic influenza but for other communicable diseases or other types of public health event that might cause a public health emergency (ICAO, no date). The ICAO has published guidelines for states concerning the management of communicable diseases posing a serious public health risk (ICAO, 2009). These guidelines are generic, in that they are applicable to many communicable diseases, not only influenza, and can form the basis for the management of other types of public health events, such as a nuclear power plant explosion that may emit a radioactive plume that impinges on aircraft routes. They will continue to be modified as more information is gained on preparedness planning. They are based on the WHO International Health Regulations (WHO, 2016), and use-planning around airports is crucial for minimizing the impact of aviation accidents by ensuring safety for both air and ground populations. It involves controlling land use within a defined area around the airport to reduce the risk of accidents and potential consequences. This includes zoning regulations, height restrictions, and population density controls to minimize potential casualties and damage from aviation incidents (FAA, 2022).

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World Health Organization (WHO), 2016. International Health Regulations, 2005. 3rd Edition. https://iris.who.int/bitstream/handle/10665/246107/9789241580496-eng.pdf Accessed 20 May 2025.

Coordinating agency or organisation

United Nations Economic Commission for Europe (UNECE) in collaboration with the International Civil Aviation Organisation (ICAO).

Preliminary – Corrections Pending

TL0402 / TECHNOLOGICAL / Transportation Accidents

Inland Water Ways Transportation Accident

Definition

An inland waterway transportation accident is an unwanted or unintended sudden event or a specific chain of such events occurring in connection with inland water vessel operations, which have harmful consequences (United Nations, European Union and the International Transport Forum at the OECD, 2019).

Reference

United Nations, European Union and the International Transport Forum at the OECD (2019). Glossary for transport statistics. 5th Edition. www.unece.org/fileadmin/DAM/trans/main/wp6/pdfdocs/Glossary_for_Transport_Statistics_EN.pdf Accessed 28 January 2025

Preliminary – Corrections Pending

Annotations

Synonyms

Not identified.

Additional scientific description

The Glossary for Transport Statistics prepared by the United Nations, the European Union and the International Transport Forum at the Organisation for Economic Co-operation and Development (2019) gives additional information for Inland Waterways Transportation Accidents, and describes these as an event that has resulted in any of the following: the death of, or serious injury to, a person that is caused by, or in connection with, the operations of an Inland Waterway Transport (IWT) vessel; or the loss of a person from an IWT vessel that is caused by, or in connection with, the operations of an IWT vessel; or the loss, presumed loss or abandonment of an IWT vessel; or material damage to an IWT vessel; or the stranding or disabling of an IWT vessel, or the involvement of an IWT vessel in a collision; or material damage to the inland waterways' infrastructures external to a vessel that could seriously endanger the safety of the vessel or another vessel or an individual; or damage to the environment brought about by the damage of an IWT vessel or IWT vessels being caused by, or in connection with, the operations of an IWT vessel or IWT vessels. (United Nations, European Union and the International Transport Forum at the OECD, 2019)

Any accident in connection with the normal operation of the vessel, including when it is in port or at anchor, is covered. Harmful consequences of inland waterways transportation accidents may include fatalities, injuries, environmental damage, or infrastructure loss,

Metrics and numeric limits

Statistically agreed metrics for an Inland Waterway Accident are as follows (European Union and the International Transport Forum at the Organisation for Economic Co-operation and Development, 2019):

- *Fatal accident:* any injury resulting in a person killed.
- *Non-fatal accident:* any injury incident other than a fatal accident.
- *Person killed:* any person killed immediately or dying within 30 days as a result of an injury accident excluding suicides.
- *Person injured:* any person who as a result of an injury accident was not killed immediately or not dying within 30 days but sustained an injury, normally needing medical treatment, excluding attempted suicides.

A suicide or an attempted suicide is a deliberate act to injure oneself fatally and is therefore not considered an accident. However, if a suicide or an attempted suicide causes injury to another person on an IWT vessel, then this is regarded as an injury accident (United Nations, European Union and the International Transport Forum at the Organization for Economic Co-operation and Development, 2019).

Key relevant UN convention / multilateral treaty

The multilateral convention relating to the limitation of the liability of owners of inland navigation vessels (CLN) (UN Treaty Collection, 1973).

Inland Waterways & Environmental Protection OECD, 2021

The UN Convention on the Law of the Non-Navigational Uses of International Watercourses (UN Watercourses Convention, UNWC) is a significant international treaty adopted by the UN General Assembly on May 21, 1997. It promotes cooperation among watercourse states, and establishes fundamental principles and rules regarding the use, management, and protection of international watercourses (United Nation, 1997).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: The United Nations, European Union and the International Transport Forum at the Organisation for Economic Co-operation and Development (2019) detail drivers of this hazard as collision, storm, overloading, stability failure, excessive current, and bottom damage. Issues such as low visibility from weather and other issues and human error are associated with inland waterways transportation accidents. For malicious acts refer to societal hazards.

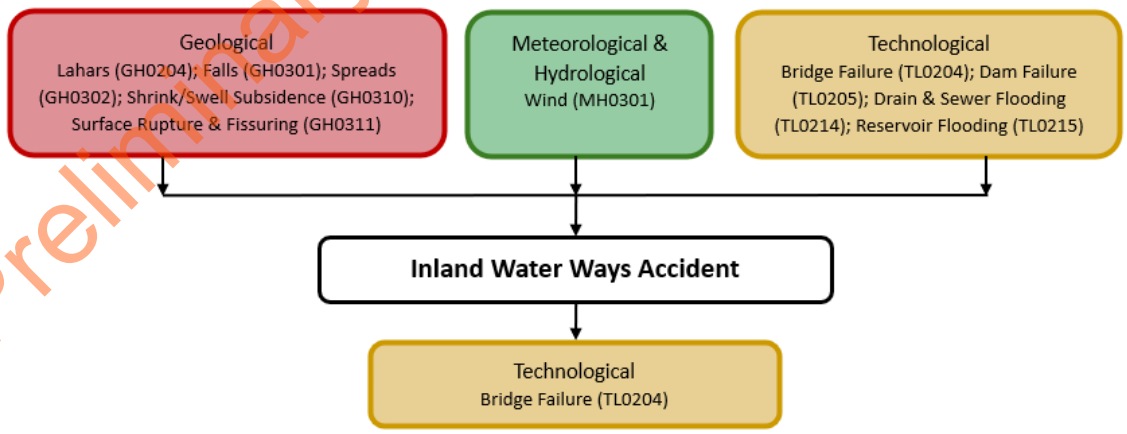
As an example of an inland waterway transport accident, a large container ship named the Ever Given ran aground after apparently being hit by a sudden strong wind in the Suez Canal, causing a major global shipping disruption in March 2021. The Ever Given, which is 400 meters long, ran aground and became wedged sideways across the waterway. This caused a traffic jam of over 300 vessels, including bulk carriers and oil tankers. The blockage lasted for six days before the ship was refloated. Many supply chain impacts occurred as a result (SAFETY4SEA, 2023).

Impacts: In a report from the European Conference of Ministers of Transport, data showed that most accidents in inland waterway transport do not lead to human losses, but only to damage to the infrastructure, vessel and perhaps cargo (ECMT, 2006).

In a report for the Department of Transport and Regional Economics by the University of Antwerp, Netherlands on innovative inland navigation, Verberght (2019) identified that it is difficult to find reliable accident data in inland navigation and that the main cause of accidents in inland waterway transportation is human errors. Accidents usually cost time, not only for those who are part of the accident, but also for all the vessels that are obliged to wait until the wreckage is salvaged (Verberght, 2019).

Inland water locations consistently account for more than half of all accidental drowning deaths in the UK, on average 250 each year. In almost half of all known incidents, the person had no intention of being in the water (ROSPA, 2018).

Multi-hazard Context: The figure below summarises common interactions between inland waterways transportation accidents and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Many hazards impact on the multi-hazard context of inland waterways transportation accidents and include storms causing vessels to capsize as well as wind, fog, floods, and droughts as well as excessive currents and collisions leading to oil spills from accidents, and health impacts such as waterborne disease outbreaks following vessel accidents. Impacts on supply chains are of import.

Monitoring: Real-time data such as vessel positions, speed, and direction **are** used to monitor the situation in inland waterways. It calculates collision probabilities and issues alerts with recommendations for avoiding accidents. The system relies on technologies like AIS and radar to continuously monitor vessel movements. Improving decision-making, helps prevent accidents and enhances safety in inland waterway transportation (Cheng et al., 2020).

In both Europe and Asia, River Information Services (RIS) are well-documented and utilized for policy and planning, particularly in the context of inland navigation. The European Union, for example, has a directive (2005/44/EC) on harmonized RIS to ensure

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safety, efficiency, and environmental protection of inland waterways (EUR-Lex, 2005). Similar systems are also used in various Asian countries to improve navigation and traffic management.

In the UK, the scope of the Merchant Shipping (Accident Reporting and Investigation) regulations means that the Navigation Authorities have a duty to report accidents and serious injuries to the Chief Inspector of Marine Accidents and investigate and report on the circumstances, including making recommendations to prevent a recurrence. (AINA, 2015)

Risk Management: The UK Inland Waterways Association Safety Policy (2012) presents information on the roles and responsibilities of those involved in their association and subsidiaries to prevent and reduce the risk of accidents occurring. The UK Marine Accident Investigation Branch, under regulations via the Merchant Shipping Act, can undertake investigations with the following remit: "The sole objective of the investigation of an accident... shall be the prevention of future accidents through the ascertainment of its causes and circumstances. It shall not be the purpose of an investigation to determine liability nor, except so far as is necessary to achieve its objective, to apportion blame" (ROSPA, 2018).

The US Coastguard, in 2024, published their USCG Amalgamated Navigation Rules International & U.S. Inland in 2023 This amalgamation of the International Regulations for Preventing Collisions at Sea (72 COLREGS), and the U.S. Inland Navigation Rules (33 CFR 83), as amended; their Annexes; and, some associated provisions, and adopts a single compact layout that denotes textual differences between each set of Rules.(USCG, 2024).

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Coordinating agency or organisation

United Nations Economic Commission for Europe (UNECE).

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TL0403 / TECHNOLOGICAL / Transportation Accidents

Maritime Accident

Definition

A maritime accident is an event, or a sequence of events, that has resulted in any of the following occurring directly in connection with the normal operation of a marine vessel: the death of, or serious injury to, a person; the loss of a person from a ship; the loss, presumed loss or abandonment of a marine vessel; material damage to a marine vessel; the stranding or disabling of a marine vessel, or the involvement of a marine vessel in a collision; material damage to the marine infrastructures external to a vessel, that could seriously endanger the safety of the vessel or another vessel or an individual; and severe damage to the environment, or the potential for severe damage to the environment, brought about by the damage of a marine vessel (United Nations, European Union and the International Transport Forum at the OECD, 2019).

Reference

United Nations, European Union and the International Transport Forum at the OECD (2019). Glossary for transport statistics. 5th Edition. www.unece.org/fileadmin/DAM/trans/main/wp6/pdfdocs/Glossary_for_Transport_Statistics_EN.pdf Accessed 11 February 2025.

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Annotations

Synonyms

Shipping accident, marine casualty, or vessel accident.

Additional scientific description

Statistically agreed definitions for Marine Accident (United Nations, European Union and the International Transport Forum at the OECD, 2019) are as follows:

- *Fatal accident:* any injury resulting in a person killed.
- *Non-fatal accident:* any injury incident other than a fatal accident.
- *Person killed:* Any person killed immediately or dying within 30 days as a result of an injury accident. *For countries that do not apply the threshold of 30 days, conversion coefficients are estimated so that comparisons on the basis of the 30 day-definition can be made.*
- *Person lost at sea:* A person missing at sea, being presumed to have gone overboard.
- *Person Injured:* Any person who as result of an injury accident was not killed but sustained an injury.
- *Serious injury:* An injury which is sustained by a person in a casualty resulting in incapacitation for more than 72 hours commencing within seven days from the date of injury.
- *Person seriously injured:* Any person who as result of an injury accident was seriously injured.

- *Person slightly injured:* Any person who as result on an injury accident was not seriously injured. *Very serious marine casualty:* A casualty to a marine vessel which involves the total loss of the marine vessel, loss of life or severe damage to the environment.
- *Serious marine casualty:* A casualty which does not qualify as a very serious casualty and which involves a fire, explosion, grounding, contact, heavy weather damage, ice damage, hull cracking or suspected hull defect, etc., resulting in: structural damage rendering the marine vessel not navigable, such as penetration of the hull underwater, immobilisation of the main engines, extensive accommodation damage etc.; or pollution (regardless of quantity); and/or a breakdown necessitating towage or shore assistance.
- *Marine incident:* An occurrence or event being caused by, or in connection with, the operations of a marine vessel in motion at sea, other than a marine casualty that endangered, or, if not corrected, would endanger the safety of the vessel, its occupants or any other person or the environment.

Metrics and numeric limits

International Maritime Organization (IMO) is the United Nations agency with responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships. The IMO's work supports the United Nations Sustainable Development Goals (IMO, 2019). Reporting to IMO of marine safety investigations and marine casualties and incidents are based on the following IMO instruments (IMO, no date a):

- Code of International Standards and Recommended Practices for a Safety Investigation into a Marine Casualty or Marine Incident (Casualty Investigation Code), 2008 edition (resolution MSC.255(84)).
- Safety of fishermen at sea, resolution A.646(16), paragraph 3.
- Reports on casualty statistics concerning fishing vessels and fishermen at sea, MSC/Circ.539/Add.2.
- Report on fishing vessels and fishermen statistics, MSC/Circ.753.
- Provision of preliminary information on serious and very serious casualties by rescue co-ordination centres, MSC/Circ.802.
- Guidance on near-miss reporting, MSC-MEPC.7/Circ.7, paragraph 4.
- Casualty-related matters, Reports on marine casualties and incidents, MSC-MEPC.3/Circ.4/Rev.1.
- Guide on the process of Reporting a marine casualty and incident to IMO; and reviewing the analysis of a marine safety investigation report submitted to IMO, which is a user guidance for the Global Integrated Shipping Information System (GISIS) module on marine casualties and incidents.
- Guide on the process to Associate interest to a Marine Safety Investigation report, which is regarding how Member States can be associated to a Marine Safety Investigation report previously uploaded into GISIS-MCI.
- Global Integrated Shipping Information System summarises key metrics such as number of very serious casualties/year (IMO, no date b)

Key relevant UN convention / multilateral treaty

United Nations Convention on the Law of the Sea (United Nations, 1982).

International Convention for the Safety of Life at Sea, (SOLAS) 1974 (IMO, 1974)

Examples of hazard drivers, impacts and risk management

Hazard Drivers: The causes of marine accidents include collision, close quarters and contact accidents; grounding; fire; explosion; lifeboat (lack of training and/or maintenance); inadequate risk management; operational failure; cargo-related; human error; third party deficiency; technical failure and weather and other environmental factors (Acejo et al., 2018).

The most common kind of accident was identified as 'collision, close quarters and contact' (35.8%). This was followed by grounding which constituted 17% of the cases. About 9.8% of cases were associated with fire and explosion, 3.3% of cases were related to lifeboats and 34.2% were described by investigators as being other kinds of accidents. These disparate events included, for example, crane failure, man overboard, cargo loss, engine room flooding, trip and fall, parting of mooring lines, and oil spills. (Acejo et al., 2018).

Impacts: Acejo et al. (2018) reported a total of 693 accident reports which were analysed to help users gauge the severity of total fatalities or injury counts. These were identified from an analysis of accident investigation reports that were published online by the (UK) Marine Accident Investigation Branch (MAIB), the Australian Transport Safety Bureau (ATSB), the (US) National Transportation Safety Board (NTSB), the Federal Bureau of Maritime Casualty

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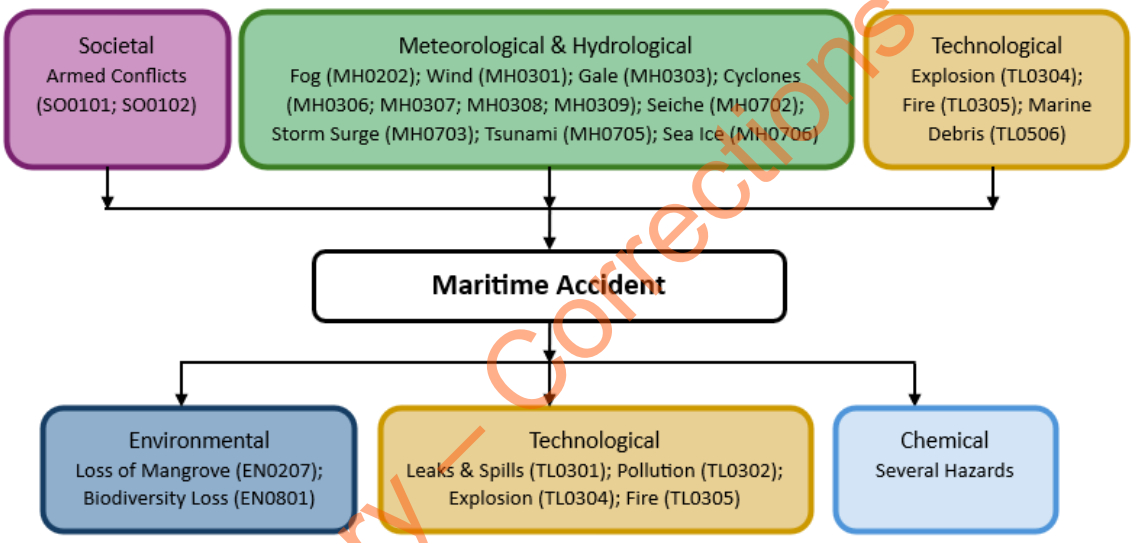
Investigation in Germany, and the Danish Maritime Accident Investigation Board (DMAIB) in the period 2002-2016 (inclusive) and accident investigation reports from Maritime New Zealand from 2002-4, as this publication was discontinued in 2004. (Acejo et al., 2018).

The most common kind of accident was identified as 'collision, close quarters and contact' (35.8%). This was followed by grounding which constituted 17% of the cases. About 9.8% of cases were associated with fire and explosion, 3.3% of cases were related to lifeboats and 34.2% were described by investigators as being other kinds of accidents. These disparate events included, for example, crane failure, man overboard [sic], cargo loss, engine room flooding, trip and fall, parting of mooring lines, and oil spills. 'Inadequate risk management' was most identified as both an immediate and a contributory cause of accidents when all types were aggregated with third-party deficiency' is the second most common accident cause identified by investigators. 'Failure in communication' was the third most identified cause of accidents (Acejo et al., 2018).

It needs to be acknowledged that the 695 accident reports dataset was primarily from developed maritime nations; global applicability might be limited without further regional context.

Multi-hazard Context: The figure below summarises common interactions between maritime accidents and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: AIS (Automatic Identification System) and VDR (Voyage Data Recorder) as essential components in real-time monitoring and investigations.

The Automatic Identification System (AIS) is a maritime safety and navigation tool that uses radio communication to exchange information between vessels and shore stations. It helps vessels avoid collisions, track vessel movements, and provide information to authorities for traffic management. AIS transponders are designed to be capable of providing position, identification and other information about the ship to other ships and to coastal authorities automatically (IMO, no date c).

Voyage Data Recorders (VCR) Passenger ships and ships other than passenger ships of 3000 gross tonnage and upwards constructed on or after 1 July 2002 must carry voyage data recorders (VDRs) to assist in accident investigations, under regulations adopted in 2000, which entered into force on 1 July 2002. The mandatory regulations are contained in Chapter V on Safety of Navigation of the International Convention for the Safety of Life at Sea, 1974 (SOLAS). Like the black boxes carried on aircraft, VDRs enable accident investigators to review procedures and instructions in the moments before an incident and help to identify the cause of any accident. (IMO, no date d)

The European Marine Casualty Information Platform (EMCIP) was operational from June 2011. The European Marine Casualty Information Platform (EMCIP) is a database and a data distribution system operated by the European Maritime Safety Agency (EMSA), the European Commission and the EU/EEA Member States (EMSA, no date). It aims to deliver a range of potential benefits at national and European relevance by:

- Improving the information background about marine casualties and incidents;
- Widening and deepening the analysis of the results of casualty investigations;
- Providing at-a-glance information, enabling general risk identification and profiling;

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- Sharing lessons learned and safety issues detected in the course of safety investigations.

Risk Management: The IMO has established an International Safety Management (ISM) Code that seeks to establish systems for the safe operation and management of ships and for pollution prevention (IMO, 1993). The Code's origins go back to the late 1980s, when there was mounting concern about poor management standards in shipping. Investigations into accidents revealed major errors on the part of management, and in 1987 the IMO Assembly adopted resolution A.596(15), which called upon the Maritime Safety Committee to develop guidelines concerning shore-based management to ensure the safe operation of ro-ro passenger ferries. The procedures required by the Code should be documented and compiled in a Safety Management Manual, a copy of which should be kept on board (IMO, 1998).

Clarify how the ISM Code's implementation is monitored (e.g., through audits or port state control). Consider briefly referencing Safety Management Certificates (SMCs) issued to vessels.

IMO Safety Management Certificates (SMCs) are issued to vessels to verify their compliance with the International Safety Management (ISM) Code, which outlines standards for safe ship operation and management (IMO, 1995). An SMC signifies that the vessel's company and shipboard management operate according to an approved Safety Management System (SMS). The certificate is valid for five years and requires at least one intermediate verification within that period.

The ISM Code's implementation is monitored through various mechanisms, including audits and port state control. Audits, conducted by the Administration (flag state) or Recognized Organizations (ROs), verifying compliance with the ISM Code's requirements (IMO, no date e). Port state control involves inspections of ships in foreign ports to ensure they meet international standards, including the ISM Code. (IMO, no date f)

IMO has various guidelines that contribute to real-time risk mitigation including the threat posed by piracy and armed robbery against ships has been on the IMO's agenda since the early 1980s (IMO, no date g).

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Coordinating agency or organisation

Not identified

Preliminary – Corrections Pending

TL0404 / TECHNOLOGICAL / Transportation Accidents

Rail Accident

Definition

A rail accident is a sudden event or a specific chain of such events (occurring during train operation) which has harmful consequences (United Nations, European Union and the International Transport Forum at the OECD, 2019).

Reference

United Nations, European Union and the International Transport Forum at the OECD (2019). Glossary for transport statistics. 5th Edition. www.unece.org/fileadmin/DAM/trans/main/wp6/pdfdocs/Glossary_for_Transport_Statistics_EN.pdf Accessed 28 January 2025

Preliminary – Corrections Pending

Annotations

Synonyms

Train crash, Train wreck, Railroad accident.

Additional scientific description

United Nations, European Union and the International Transport Forum at the Organisation for Economic Co-operation and Development Glossary (2019) states that the statistically agreed definitions for Rail Accident are as follows (United Nations, European Union and the International Transport Forum at the OECD, 2019):

- *Accident:* An unwanted or unintended sudden event or a specific chain of such events (occurring during train operation) which has harmful consequences.
- *Incident:* Any occurrence, other than an accident, highlighting a potential safety issue in railway operations. (*Sometimes also referred to as accident precursor, or near-miss.)*
- *Significant accident:* Any accident involving at least one rail vehicle in motion, resulting in at least one killed or seriously injured person, or significant damage to stock, track, other installations or environment, or extensive disruption to traffic. Accidents in workshops, warehouses and depots are excluded. *This definition is used by the UIC (Union Internationale des Chemins de Fer).*
- *Significant damage to stock, track, other installations or environment:* Damage that exceeds an internationally agreed threshold. (*The threshold for significant damage, adopted by the UIC, was set at EUR 150,000 in 2007.)*
- *Extensive disruption to traffic:* Extensive disruption to traffic occurs when train services on at least one main railway line are suspended for more than six hours.
- *Injury accident:* Any accident involving at least one rail vehicle in motion, resulting in at least one killed or injured person. Accidents in workshops, warehouses and depots are excluded. (*This definition includes accidents with slightly injured persons and is similar to that used in road accident statistics.)*
- *Serious injury accident:* Any accident involving at least one rail vehicle in motion, resulting in at least one killed or seriously injured person. Accidents in workshops, warehouses and depots are excluded. (*This definition is normally used by the UIC for railway accidents and excludes the accidents with slightly injured persons. Figures collected under this definition cannot be compared directly to the number of road accidents which includes accidents with slightly injured persons.)*

- *Casualty:* Any person killed or injured as a result of an injury accident, excluding attempted suicides.
- *Person killed:* Any person dying immediately or within 30 days as a result of an injury accident, excluding suicide. (*It includes passengers, employees and other specified or unspecified persons involved in a rail injury accident. A killed person is excluded if the competent authority declares the cause of death to be suicide, i.e., a deliberate act to injure oneself resulting in death. For countries that do not apply the threshold of 30 days, conversion coefficients are estimated so that comparisons on the basis of the 30 day-definition can be made.)*
- *Person injured:* Any person who as a result of an accident was not killed immediately or not dying within 30 days, but sustained an injury, normally needing medical treatment, excluding attempted suicide. (*Injuries include cases such as, but not limited to, a cut, fracture, sprain, or amputation. Persons with lesser wounds, such as minor cuts and bruises are not normally recorded as injured. An injured person is excluded if the competent authority declares the cause of the injury to be attempted suicide by that person, i.e., a deliberate act to injure oneself resulting in injury, but not in death.)*
- *Person seriously injured:* Any person injured who was hospitalised for more than 24 hours as a result of an accident, excluding attempted suicide.
- *Person slightly injured:* Any person injured normally needing medical treatment, excluding attempted suicide, not classified as seriously injured. (*Persons with lesser wounds, such as minor cuts and bruises are not normally recorded as injured.)*
- *Collision:*
  - Collision of two or more rail vehicles (*Any front to front, front to end or a side impact between a part of a train and a part of another train or rail vehicle, or with shunting rolling stock).*
  - Collision of rail vehicle with an obstacle within the clearance gauge (*An impact between a part of a train and objects fixed or temporarily present on or near the track (except at level crossings if lost by a crossing vehicle or user), including impacts with overhead contact lines).*
- *Derailment:* Any case in which at least one wheel of a train leaves the rails. (*Derailments as a result of collisions are excluded. These are classified as collisions.)*
- *Level crossing accidents:* Any accident at a level crossing involving at least one railway vehicle and one or more crossing vehicles, other users of the road such as pedestrians or other objects temporarily present at or near the track (*Sometimes also referred to as grade crossing accident.)*
- *Accidents to persons caused by rolling stock in motion:* Accidents to one or more persons that are either hit by a railway vehicle or part of it or hit by an object attached to it or that has become detached from the vehicle. Persons that fall from railway vehicles are included, as well as persons that fall or are hit by loose objects when travelling on-board vehicles.
- *Fires in rolling stock:* Fires and explosions that occur in railway vehicles (including their load) when they are running between the departure station and the destination, including when stopped at the departure station, the destination station or intermediate stops, as well as during re-marshalling operations.
- *Accident involving the transport of dangerous goods:* Any accident or incident that is subject to reporting in accordance with the Regulation concerning the International Carriage of Dangerous Goods by Rail (OTIF, 2021).
- *Suicide:* An act to deliberately injure oneself resulting in death, as recorded and classified by the competent national authority.
- *Attempted suicide:* An act to deliberately injure oneself resulting in serious injury, but not in death, as recorded and classified by the competent national authority.
- Category of person in railway accident statistics:
- *Rail passenger:* Any person, excluding members of the train crew, who makes a trip by rail. For accident statistics, passengers trying to embark/disembark onto/from a moving train are included.
- *Employees or contractor:* Any person whose employment is in connection with a railway and is at work on duty at the time of the accident. It includes the crew of the train and persons handling rolling stock and infrastructure installations.
- *Level crossing user:* Persons using a level crossing to cross the railway line by any means of transportation or by foot.
- *Trespasser (unauthorised persons on railway premises):* Any persons present in railway premises where such

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presence is forbidden, with the exception of level crossing users.

- *Others:*
  - *Other person at platform:* means any person at a railway platform who is not defined as 'passenger', 'employee or contractor', 'level crossing user', 'other person not at a platform' or 'trespasser'.
  - *Other person not at platform:* means any person not at a railway platform who is not defined as 'passenger', 'employee or contractor', 'level crossing user', 'other person at a platform' or 'trespasser'.

Metrics and numeric limits

Not reported globally.

Key relevant UN convention / multilateral treaty

Not identified.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Collisions, derailments, level crossing accidents, accidents to persons caused by rolling stock in motion, and fires in rolling stock (United Nations, European Union and the International Transport Forum at the OECD, 2019). Natural hazards significantly exacerbate the challenges faced by already stressed railway infrastructure, primarily due to overloaded networks. Floods, heavy rainfall, earthquakes, cyclones, heavy snowfall, low visibility due to fog and landslides are major causes of rail accidents. For example, cyclones can damage trees along tracks, disrupting transport, while powerful cyclones may also damage bridges (Joshi et al., 2024).

The intensification of commuting flows along rail corridors creates varying safety challenges based on industry-specific travel patterns. Research shows that commuting inefficiency varies significantly across economic sectors (Ling et al., 2024), which can lead to temporal congestion patterns around rail infrastructure. These patterns, when combined with increasing urbanization along rail corridors, create distinct accident vulnerability profiles that require targeted mitigation strategies.

Impacts: Railway accidents have significant impacts, including potential fatalities and injuries, extensive disruptions to train services, and damage to railway infrastructure and the environment (Hong et al. 2023). Accidents can also lead to psychological impacts on survivors (Maltais et al, 2022). and economic consequences for the rail industry and affected communities.

Railway accidents involving chemical, nuclear, and explosive cargo are a serious concern due to the potential for widespread harm and environmental damage. Several incidents highlight the risks associated with transporting such materials by rail, including derailments, collisions, and explosions. As an example, on February 3, 2023, a Norfolk Southern freight train carrying hazardous materials from Madison, Illinois, to Conway, Pennsylvania, derailed in East Palestine, Ohio. Of the 150 rail cars, 38 derailed; 11 of those 38 cars contained hazardous chemicals that derailed, igniting and fuelling fires that damaged 12 other non-derailed cars (Welsh et al, 2024)

As an example of a railway accident with significant impacts, Maltais et al (2023) reported that on the night of July 6, 2013, a train comprised of 63 tank cars carrying crude oil derailed in the downtown area of Lac-Mégantici (QC, Canada). The derailment triggered explosions, burning a large portion of the city centre, killing 47 people and destroying 66 homes and 44 businesses. This event also forced the evacuation of over 2000 people, of a population of 6000 inhabitants. The entire population experienced the impact of this technological disaster, caused by a lack of railway track maintenance and human neglect, among others (Maltais et al, 2022).

Multi-hazard Context: The figure below summarises common interactions between rail accidents and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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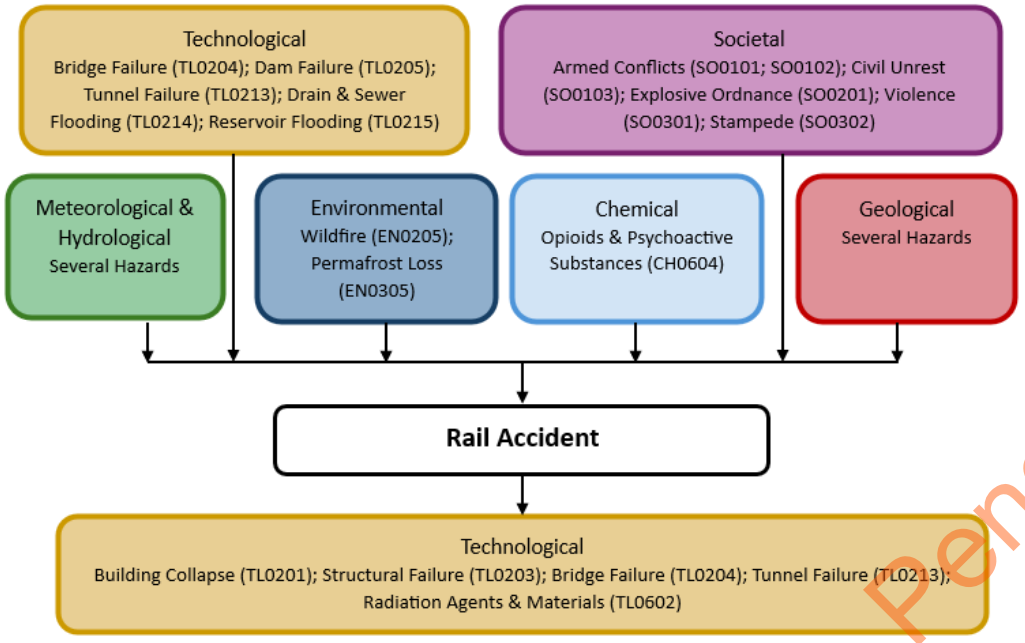

Monitoring: Early detection and preventive maintenance of potential rail accidents before they occur have proven to be highly cost-effective. Continuous monitoring of critical components not only enhances safety but also significantly boosts infrastructure availability, as monitoring systems enable repairs or replacements during routine maintenance periods. As a result, the railway industry and researchers worldwide have been developing integrated, robust methods for ongoing monitoring and maintenance of railway infrastructure. With advancements in sensors and information technology, the health of railway infrastructure is now continuously tracked using sensors on rolling stock (such as for rail and pantograph monitoring), near the track (such as for switch engine monitoring), and through crowd-sensing techniques (e.g., mobile phones measuring vibrations, temperature, pressure, etc.). This ongoing monitoring helps manage railway system performance. Additionally, databases built from continuous data collection grow over time, creating challenges in transmission, storage, and analysis. For example, high-frequency data from onboard axle box acceleration systems and laser Doppler vibrometers face difficulties in being transferred to cloud systems or databases due to existing communication bandwidth limitations. To address this, data pre-processing and on-premises analytics could help reduce the data load. Moreover, new standards are necessary for managing data from multiple measurement sources and emerging sensing technologies, such as satellite data. In summary, the railway industry and academia are actively addressing these challenges, with increased collaboration potentially unlocking optimal solutions and overcoming barriers to the adoption of AI. (Phusakulkajorn et al., 2023).

Effective rail safety monitoring requires integration across multiple urban scales and systems. Urban systems science approaches that connect micro-level rail operations with macro-level urban development patterns can identify emerging safety risks before traditional monitoring detects them (Yang & Zhang, 2025). This integration is particularly powerful when combined with digital twin technologies that simulate interactions between transportation networks and urban development, providing predictive risk assessment capabilities rather than just reactive monitoring (Fang et al.,2022).

Risk Management: The Railway Safety Directive was published with the purpose of establishing and improving rail safety and security standards across the European Union (ORR, 2004). This framework also includes Common Safety Targets (CST) to develop and improve safety performance (European Union Agency for Railways, 2023).

It should be noted that, in contrast to other modes of transport, a large majority of rail accident fatalities occur to level crossing users or trespassers on rail tracks, as opposed to railway passengers (European Union Agency for Railways, 2020). This thus presents different hazard management challenges than for other modes of transport.

Rail safety risk management should consider wider transportation network changes and their socioeconomic implications. Recent research across China's Yangtze River Delta shows that transport network modifications produce varying socioeconomic effects across different urban contexts (Qu et al., 2024). These insights should inform risk management strategies around rail infrastructure, particularly regarding land use regulations and infrastructure investment priorities. A regional, network-based approach to risk management can identify vulnerable nodes where accident impacts would have disproportionate socioeconomic consequences, enabling more targeted mitigation measures.

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Coordinating agency or organisation

United Nations Economic Commission for Europe (UNECE).

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TL0405 / TECHNOLOGICAL / Transportation Accidents

Road Traffic Accident

Definition

A road traffic accident involving at least one road vehicle in motion on a public road or private road to which the public has right of access, resulting in at least one injured or killed person (adapted from UNECE, Eurostat, ITF, 2019 and WHO, 2023a).

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Annotations

Synonyms

Traffic accident, Road Traffic Injury, Motor vehicle collision, Motor vehicle accident, Car accident, Automobile accident, Road traffic collision, Car crash

Additional scientific description

More than 90% of road traffic deaths occur in low- and middle-income countries. Road traffic death rates are highest in the WHO African Region and lowest in the European Region. Even within high-income countries, people from lower socioeconomic backgrounds are more likely to be involved in road traffic crashes. Road traffic injuries are the leading cause of death for children and young adults aged 5-29 years. Two-thirds of road traffic fatalities occur among people of working age (18-59 years), Males are typically 3 times more likely to be killed in road crashes than females (WHO 2923 a).

Statistically agreed definitions for road transport accidents (United Nations, European Union and the International Transport Forum at the OECD (2019) are as follows: *Injury accident:* Any accident involving at least one road vehicle in motion on a public road or private road to which the public has right of access, resulting in at least one injured or killed *person. (A suicide or an attempted suicide is not an accident, but an incident caused by a deliberate act to injure oneself fatally. However, if a suicide or an attempted suicide causes injury to another road user, then the incident is regarded as an injury accident.)*

Injury accidents include collisions between road vehicles; between road vehicles and pedestrians; between road vehicles and animals or fixed obstacles and with one road vehicle alone. Included are collisions between road and rail vehicles. Multivehicle collisions are counted as only one accident provided that any successive collisions happen within a very short period. Injury accidents exclude accidents incurring only material damage. Injury accidents exclude terrorist acts but include:

- *Fatal accident:* Any injury accident resulting in a person killed.
- *Non-fatal accident:* Any injury accident other than a fatal accident.
- *Casualty:* Any person killed or injured as a result of an injury accident.
- *Person killed:* Any person killed immediately or dying within 30 days as a result of an injury accident, excluding suicides. (*A killed person is excluded if the competent authority declares the cause of death to be suicide, i.e., a deliberate act to injure oneself resulting in death. For countries that do not apply the threshold of 30 days, conversion coefficients are estimated so that comparisons on the basis of the 30 day-definition can be made.)*
- *Person injured:* Any person who as result of an accident was not killed immediately or not dying within 30 days, but sustained an injury, normally needing medical treatment, excluding attempted suicides. (*Persons with lesser wounds, such as minor cuts and*

bruises are not normally recorded as injured. An injured person is excluded if the competent authority declares the cause of the injury to be attempted suicide by that person, i.e., a deliberate act to injure oneself resulting in injury, but not in death.)

- *Person seriously injured:* Any person injured who was hospitalized for a period of more than 24 hours.
- *Person slightly injured:* Any person injured excluding persons killed or seriously injured. (*Persons with lesser wounds, such as minor cuts and bruises are not normally recorded as injured.)*
- *Maximum abbreviated injury scale (MAIS):* The Maximum Abbreviated Injury Scale is a medical classification on the severity of injuries. MAIS 1-2 is regarded as slight injuries and 3-6 as serious injuries. *(Other classifications can be used if they can be transcoded to MAIS.)*
- *Driver involved in an injury accident:* Any person involved in an injury accident who was driving a road vehicle at the time of the accident.
- *Passenger involved in an injury accident:* Any person involved in an injury accident, other than a driver, who was in or on a road vehicle, or in the process of getting in or out of a road vehicle.
- *Pedestrian Involved in an injury accident:* Any person involved in an injury accident other than a passenger or driver as defined above. *(Included are occupants or persons pushing or pulling a child's carriage, an invalid chair, or any other small vehicle without an engine. Also included are persons pushing a cycle, moped, roller-skating, skateboarding, skiing or using similar devices.)*
- *Accident between road vehicle and pedestrian:* Any injury accident involving one or more road vehicles and one or more pedestrians. *(Included are accidents irrespective of whether a pedestrian was involved in the first or a later phase of the accident and whether a pedestrian was injured or killed on or off the road.)*
- *Single-vehicle road accident:* Any injury accident in which only one road vehicle is involved. *(Included are accidents of vehicles trying to avoid collision and veering off the road, or accidents caused by collision with obstruction or animals on the road. Excluded are collisions with pedestrians and parked vehicles.)*
- *Multi-vehicle road accident:* Any injury accident involving two or more road vehicles. The following types of injury accidents involving two or more road vehicles are:
  - Rear-end collision: collision with another vehicle using the same lane of a carriageway and moving in the same direction, slowing or temporarily halted. *(Excluded are collisions with parked vehicles.)*
  - Head-on collision: collision with another vehicle using the same lane of a carriageway and moving in the opposite direction, slowing or temporarily halted. *(Excluded are collisions with parked vehicles.)*
  - Collision due to crossing or turning: collision with another vehicle moving in a lateral direction due to crossing, leaving or entering a road. *(Excluded are collisions with vehicles halted and waiting to turn which should be classified under (a) or (b).)*
  - Other collisions, including collisions with parked vehicles: collision occurring when driving side by side, overtaking or when changing lanes; or collision with a vehicle which has parked or stopped at the edge of a carriageway, on shoulders, marked parking spaces, footpaths or parking sites, etc. *Included in B.VI-15 (d) are all collisions not covered by (a), (b) and (c). The constituent element for classification of accidents between vehicles is the first collision on the carriageway, or the first mechanical impact on the vehicle.)*
- *Accident with drivers reported to be under the influence of alcohol, drugs or medication:* Any injury accident where at least one driver is reported to be under the influence of alcohol, drugs or medication impairing driving ability, according to national regulations.
- *Suicide:* An act to deliberately injure oneself resulting in death, as recorded and classified by the competent national authority. (Designation of individual suicide must be determined by a coroner, public police officer or other public authority. *(Attempted suicide as an act of deliberately injuring oneself (not leading to the death) is excluded. Only the death of the individual(s) who committed suicide is to be reported as suicide. Therefore, a fatality caused to a person by another person who committed suicide or who attempted to commit suicide is not to be reported as a suicide.)*
- *Attempted suicide:* Act to deliberately injure oneself resulting in serious injury, but not in death, as recorded and classified by the competent national authority.

Metrics and numeric limits

Approximately 1.19 million people die each year as a result of road traffic crashes which are the leading cause of death for children and young adults aged 5-29 years with 92% of the world's fatalities on the roads occurring in low- and middle-income countries, even though these countries have around 60% of the world's vehicles. (adapted from UNECE, Eurostat, ITF, 2019 and WHO, 2023a)

Key relevant UN convention / multilateral treaty

Hague Conference on Private International Law 19: Convention of 4 May 1971 on the Law Applicable to Traffic Accidents (1971).

United Nations Treaty Collection TRANSPORT AND COMMUNICATIONS B. Road Traffic 14. Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) Geneva, 30 September 1957

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Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Human factors and unsafe conditions are the primary causes of accidents. It was estimated that human errors accounted for 95% of the causes of 5519 road traffic accidents in China from 2008 to 2012. Accidents caused by driver fatigue accounted for approximately 40% of major traffic accidents; Traffic rule violations were the main factors affecting road traffic safety. Additionally, external factors such as seasonal variations in weather can also influence road traffic safety; about 5% of road traffic accidents occurred because of factors related to various weather conditions, such as the effects of rainfall, fog, windy weather and the amount of sunshine (Yan et al., 2021). Geological hazards such as earthquakes (Mason & Brabhaharan, 2021) and landslides (Yao et al., 2023).

Risk factors also include speeding, driving under the influence of alcohol and other psychoactive substances, non-use of motorcycle helmets, seatbelts and child restraints, distracted driving such as driving whilst using mobile phones, unsafe road infrastructure, unsafe vehicles, inadequate post-crash care, and inadequate law enforcement of traffic laws (WHO 2023 a).

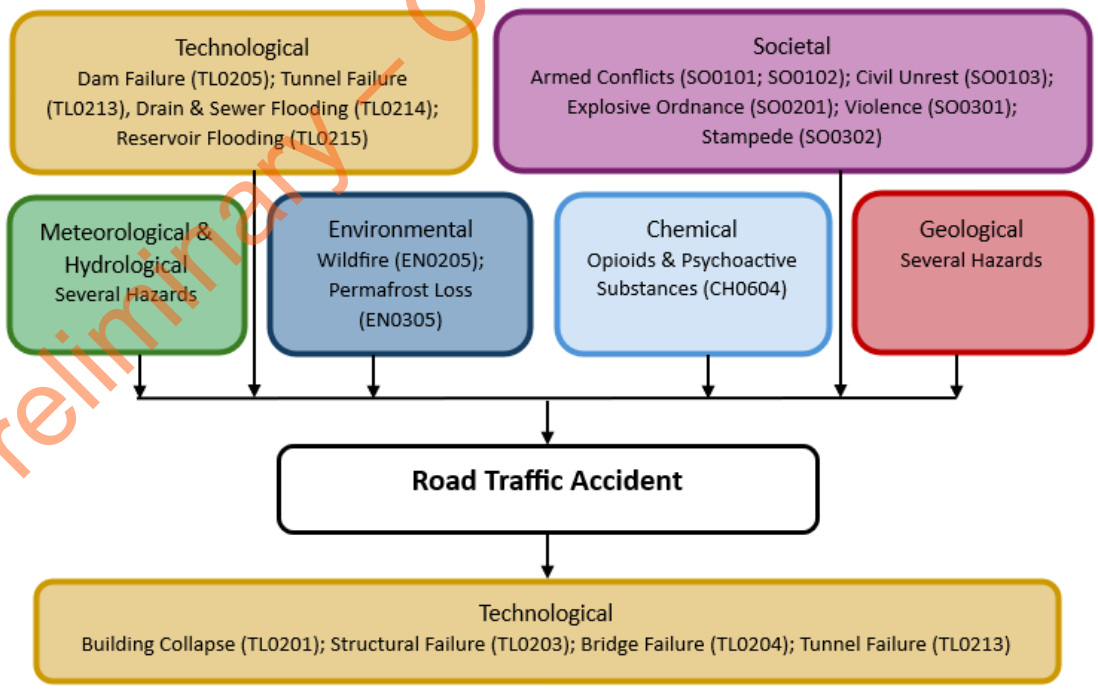
Urban layout and the built environment significantly influence road traffic accident patterns. Research has demonstrated that street network design, land use mix, and urban density are associated with traffic accident frequency and severity (Fang et al, 2024).

While electric vehicles (EVs) offer numerous benefits, concerns about the safety of their lithium-ion batteries have been raised, particularly regarding potential fire risks and explosions. Although EV fires are relatively rare compared to gasoline vehicle fires, the potential for toxic gases and the challenges of extinguishing them have prompted safety protocols and research into improving battery safety (DfT, 2023).

Impacts: As a leading cause of death and a major contributor to disability, road traffic injuries also impose an enormous economic cost on societies, estimated to be between 1 and 3 percent of Gross Domestic Product (GDP) and in some instances, as high as 6 percent (WHO, 2023). As such, they are an important health and development challenge (WHO 2023 b)

More than half of all road traffic deaths are among vulnerable road users, including pedestrians, cyclists and motorcyclists. Road traffic crashes cost most countries 3% of their gross domestic product. (WHO, 2023a).

Multi-hazard Context: The figure below summarises common interactions between road traffic accidents and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: 24-hour surveillance cameras and other sensors are available on many roads. However, increasingly effective road traffic accident monitoring requires both sophisticated data integration and advanced analytical tools. Research demonstrates that combining traditional travel surveys with location-based big data and discrete choice models can produce more accurate travel pattern estimates (Wan et al., 2021), which are essential for understanding traffic flow contexts where accidents occur. These multi-source data approaches should be complemented by AI-powered planning intelligence systems that can evaluate street network configurations for safety implications (Fang et al., 2022). Together, these methodologies enable the creation of dynamic monitoring

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systems that not only identify current accident hotspots but can predict emerging risk areas based on changing travel patterns and infrastructure configurations, allowing for proactive rather than reactive safety interventions.

Risk Management: The safe system approach to road safety aims to ensure a safe transport system for all road users. This approach takes into account people's vulnerability to serious injuries and recognizes that the system should be designed to accommodate human error. The cornerstones of this approach are safe roads and roadsides, safe speeds, safe vehicles, and safe road users, all of which must be addressed in order to eliminate fatal crashes and reduce serious injuries (WHO, 2023 a).

The 2030 Agenda for Sustainable Development has set an ambitious target of halving the global number of deaths and injuries from road traffic accidents by 2020 (United Nations, no date). The United Nations General Assembly has set an ambitious target of halving the global number of deaths and injuries from road traffic crashes by 2030 (A/RES/74/299) (UNGA 2020).

The WHO's Global Status Report on Road Safety 2023, presents information on road safety from 172 countries and territories (WHO 2023). This report is the fifth in a series and provides an overview of the road safety situation globally. The global status reports are the official tool for monitoring the Decade of Action for Road Safety (2021-2030). The World Health Organization (WHO) reported that approximately 1.19 million people lost their lives on the world's roads in 2021 - a 5% drop when compared to the 1.25 million deaths in 2010 – and up to 50 million are injured (WHO 2023).

In September 2020, the UN General Assembly adopted resolution A/RES/74/299 "Improving global road safety", proclaiming the Decade of Action for Road Safety 2021-2030, with the ambitious target of preventing at least 50% of road traffic deaths and injuries by 2030. WHO and the UN regional commissions, in cooperation with other partners in the UN Road Safety Collaboration, have developed a Global Plan for the Decade of Action, which was released in October 2021 (WHO 2021).

The Global Plan aligns with the Stockholm Declaration, by emphasizing the importance of a holistic approach to road safety and calling on continued improvements in the design of roads and vehicles; enhancement of laws and law enforcement; and provision of timely, life-saving emergency care for the injured (WHO 2021). The Global Plan also reflects the Stockholm Declaration's promotion of policies to promote walking, cycling and using public transport as inherently healthy and environmentally sound modes of transport (WHO 2020). Progress made during the previous Decade of Action for Road Safety 2011-2020 has laid the foundation for accelerated action in the years ahead. Among the achievements are the inclusion of road safety on the global health and development agenda, broad dissemination of scientific guidance on what works, strengthening of partnerships and networks, and mobilization of resources. This new Decade of Action provides an opportunity for harnessing the successes and lessons of previous years and building upon them to save more lives.

In summary, WHO works with Member States and partners across sectors to support road safety evaluation, implementation and planning. As the lead agency for road safety in the United Nations, WHO plays a key role in guiding global efforts by advocating for road safety at the highest levels, compiling and sharing good practices and raising awareness of road safety (WHO 2023 a). WHO serves as the secretariat for the United Nations Decade of Action for Road Safety 2021-2030, which aims to reduce road traffic deaths and injuries by at least 50% by 2030. This includes convening a global network of heads of national road safety agencies, producing global status reports to track progress, and providing technical assistance (WHO 2023 b). WHO works with a range of partners to provide technical support to countries. For example, WHO works with the Bloomberg Initiative for Global Road Safety (BIGRS) to reduce fatalities and injuries from road traffic crashes in a range of low- and middle-income countries (WHO 2023 a). WHO chairs the UN Road Safety Collaboration mechanism and organizes and hosts, with key partners, high-profile advocacy events such as UN Road Safety Weeks and the annual World Day of Remembrance for Road Traffic Victims (WHO 2023a).

The 4th Ministerial Conference, hosted by the Government of Morocco in February 2025, made new national road safety commitments and ministers from 100 countries and endorsed the Marrakech Declaration that calls on governments to make road safety a political priority, ensure sustained funding and to advance actions to achieve the goal of halving road deaths by 2030 (WHO, 2025).

Many accidents involving the transport of dangerous goods still occur in countries all around the world. UNECE is ready to support all countries to implement proven United Nations instruments to prevent such accidents from occurring and to reduce the severity of their consequences (UNECE, 2023). For 75 years, UNECE has provided an intergovernmental platform where countries around the world come together to forge tools for economic cooperation and negotiate and adopt UN conventions and recommendations on inland transport and elaborate updates and implementation of the conventions. The 59 UN conventions are considered indispensable for developing safe, efficient and sustainable inland transport systems. Among them, seven conventions provide legal frameworks that build safer roads and safer vehicles, safe handling of dangerous goods and ensure that we have safer drivers and safe road users (UNECE 2023). The Agreement concerning the International Transport of Dangerous Goods by Road (ADR) is one of these seven UN conventions to improve global road safety United Nations Treaty Collection 1957 (UN Treaty Collection 2025).

Urban planning strategies to reduce traffic accidents include traffic calming measures, complete street design, and integration of transportation and land use planning. Predictive models can help identify high-risk areas for targeted interventions before accidents occur (Yu et al., 2024; Fang et al. 2022).

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Preliminary – Corrections Pending

Coordinating agency or organisation

United Nations Economic Commission for Europe (UNECE) and World Health Organization (WHO).

Preliminary – Corrections Pending

TL0501 / TECHNOLOGICAL / Waste

Disaster and Conflict Waste

Definition

Disaster and conflict waste is the waste generated by the impact of a disaster or conflict, both as a direct effect of the disaster or conflict as well as in the post-disaster and post-conflict phase as a result of poor waste management (UNEP/OCHA, 2011).

Reference

UNEP/OCHA, 2011. Disaster Waste Management Guidelines. Annex X: Terminology. United Nations Environment Programme (UNEP) / United Nations Office for the Coordination of Humanitarian Affairs (OCHA). https://www.unocha.org/publications/report/world/disaster-waste-management-guidelines Accessed 29 January 2025.

Annotations

Synonyms

Disaster debris; Conflict debris.

Additional scientific description

Disaster waste includes: concrete, stone, brick, wood, steel, glass and associated hazardous building materials (e.g. asbestos); spillage of tailings, industrial toxic and hazardous waste from dumps/stacks/ landfills; clay and tar elements from damaged buildings and infrastructures; household furnishings; parts from the power and telephone grids such as electrical poles, wire, electronic equipment, transformers; parts from water and sewage distribution systems; natural debris such as clay, mud, trees, branches, bushes, palm tree leaves; chemicals, dyes and other raw materials from industries and workshops; waste from relief operations; damaged boats, cars, buses, bicycles; unexploded ordnance (e.g., landmines); waste from munitions and damaged military installations, equipment and machinery, including fuels and lubricants; waste from disaster settlements and camps including food waste, packaging materials, excreta and other wastes from relief supplies; pesticides and fertilisers; household cleaners; paint, varnish and solvents; and healthcare waste (UNEP/OCHA Joint Environment Unit, 2011; UNDP, 2016).

Metrics and numeric limits

Not available.

Key relevant UN convention / multilateral treaty

Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1989).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Disaster and conflict waste is an important factor to consider in preparedness, humanitarian response, recovery, remediation and environmental decontamination preceding or following a disaster or conflict. Response and recovery may generate various amounts of waste (e.g., irretrievably damaged or contaminated objects and structures) or waste by-products such as relief packaging (UNEP/OCHA JEU, 2024) and water run-off from disinfection procedures.

Impacts: Disaster and conflict waste can contribute to contamination of air, water and soil causing secondary impacts such as risk of vector-borne diseases as well as air pollution, water pollution and soil pollution. Several chemicals may be involved, including but not limited to, chemical warfare agents (CH0903), asbestos (CH0202), persistent organic pollutants (CH0500), and pesticides (CH0501). Long-term impacts may occur for humans and the environment.

Multi-hazard Context: The figure below summarises common interactions between disaster and conflict waste and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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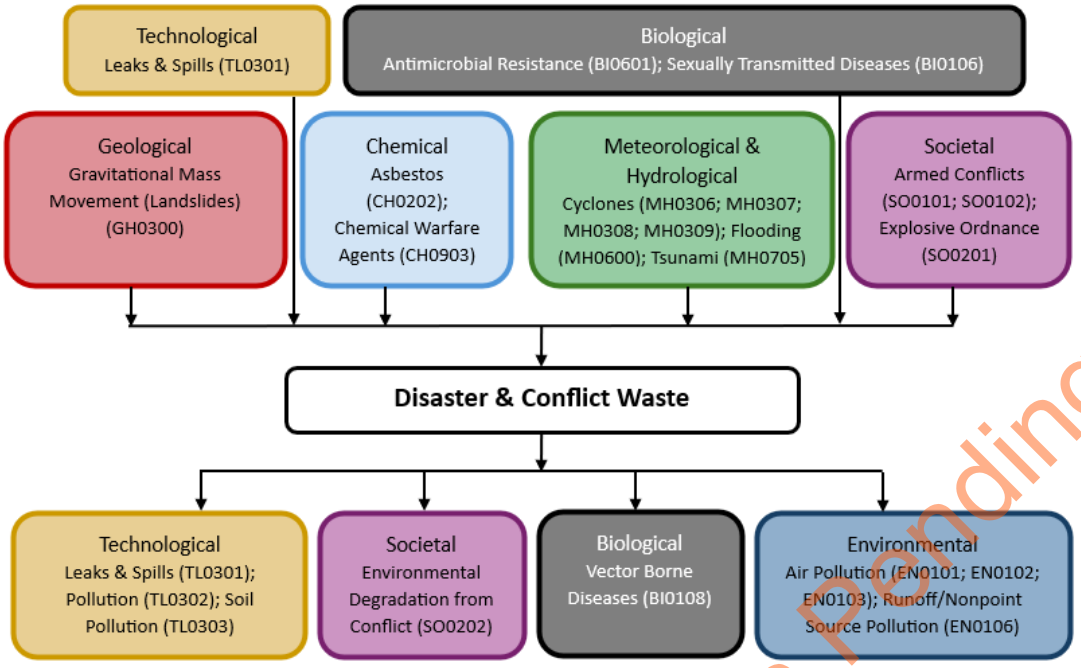

Monitoring: Developing policies and laws to achieve the goals of sustainable development, public education, improving the quality of urban planning, natural disaster insurance, and continuous monitoring of the surrounding environment are important for monitoring of waste (Naderi et al, 2025).

Risk Management: For large-scale incidents, normal waste disposal routes may be inadequate and overburdened. Laboratory analysis may be required prior to disposal to identify such properties as ignitability, corrosiveness, reactivity and toxicity, which would inform the treatment and waste disposal options (PHE, 2019; UKHSA, 2016). Material testing of recyclable materials (e.g. concrete, stone) is also required to assure compliance with national and international standards for use in relevant applications (e.g. roads).

In addressing these issues, various aspects need to be examined such as type, amount and location of waste (e.g., hazardous, non-hazardous), legislation concerning disposal site selection, capacity of disposal facilities, availability of technical expertise and equipment, agricultural and environmental impacts following disposal, potential impact of biological agents, chemical agents and radioactive materials during handling and after disposal, land and property rights, opportunities for livelihood creation, timing and speed of waste removal, human remains and societal/ethical issues (PHE, 2015; UKHSA, 2024, UN and Partners 2024). In conflict-affected/disaster settings, hazardous wastes that are frequently encountered during debris and municipal solid waste management activities include Unexploded Ordnance (UXOs), asbestos (as part of building rubble), infectious health care waste and other hazardous wastes such as expired and obsolete hazardous pesticides, equipment containing polychlorinated biphenyls (PCBs) and oils (e.g., electrical transformers) and other types of hazardous wastes (UNDP, 2016).

To the extent feasible, reuse and recycling of the waste should be prioritized to promote resource circularity, particularly of the mineral fraction which typically constitutes 70-90% of the total disaster or conflict debris by volume. For this purpose, the waste should ideally be sorted on-site during demolition operations, and if not feasible at the debris disposal or recycling site, into four main categories: i) recyclable; ii) protected; iii) non-recyclable and iv) hazardous wastes (UN and Partners, 2024).

A temporary disposal site, a place where disaster waste is safely placed, stored and processed for a predefined period after a disaster or conflict, should be selected following a rapid environmental assessment, and emissions should be minimised in relation to appropriate and available technology (UNDP, 2016).

Preliminary – Corrections Pending

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Coordinating agency or organisation

United Nations Development Programme

Preliminary – Corrections Pending

TL0502 / TECHNOLOGICAL / Waste

Solid Waste

Definition

Solid waste refers to all discarded materials, including municipal, industrial, and hazardous waste, that require systematic collection, treatment, and disposal. It excludes wastewater and emissions but includes recyclable and recoverable materials within the circular economy framework (United Nations Environment Programme, 2024).

Reference

United Nations Environment Programme, 2024. Global Waste Management Outlook 2024. https://www.unep.org/resources/global-waste-management-outlook-2024. Accessed 11 February 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Refuse, discards, trash, garbage, household waste, urban waste, municipal refuse, litter

Additional scientific description

Solid waste may include such materials as: municipal solid waste including general domestic garbage such as food waste, ash and packaging materials; human faeces disposed of in garbage; building and construction waste (including asbestos); hazardous waste (including PFAs and other chemicals); healthcare waste; and disaster waste. Examples of disaster waste include waste from damaged infrastructure, plastic water bottles, packaging from other emergency supplies and other waste from relief operations, rubble resulting from the disaster, mud and slurry deposited by the disaster, fallen trees and rocks obstructing transport and communications (WHO, 2024). Controlled waste is collected and then either recycled or disposed of in a controlled facility. Uncontrolled waste is either not collected, and thus dumped or burned in the open, or collected and then dumped or burned at its final destination (UNEP, 2024).

Low-income countries have proportionally larger rural populations, which means more people live close to locations where food is produced. In these countries, less packaging is used to transport food from rural to urban areas. Packaging therefore makes up a smaller proportion of Municipal Solid Waste (MSW). This can be seen in the composition of MSW in Sub-Saharan Africa and South America. These regions have a higher relative proportion of food waste, not because they waste more food than other regions but because there is a smaller share of packaging waste in their MSW stream. Higher-income, more urbanised populations require more packaging to transport food safely from rural to urban areas. Moreover, higher-income consumers tend to prioritise convenience, resulting in more single-use products and packaging from home deliveries and takeout food being found in the MSW stream. These consumers also have more disposable income to spend on goods such as clothing and personal hygiene products. The impact of their consumption patterns on MSW composition can be seen, for example, in MSW composition in North America and Northern and Western Europe. Other factors affecting MSW composition include climate (more garden waste may be generated in areas with high rainfall), population density and cultural practices (UNEP, 2024).

Conceptual and methodological problems of statistics on solid waste have long been identified. Across countries and regions, there are significant challenges in terms of waste data and availability. One important issue is the lack of standardisation in measurement and reporting; another is the lack of well-developed monitoring systems in many

countries, which means adequate estimates do not exist for simple indicators such as total collected waste and the share of collected waste deposited in controlled landfills. Although there are significant relationships between waste generation and indicators such as the Human Development Index, share of urban population, gross national income and adult literacy rates, analysis shows that the best model fit is linear regression using only GDP per capita, (UNEP, 2024).

Metrics and numeric limits

Global municipal solid waste generation, by householders; retailers and other small businesses; public service providers; and other similar sources, was estimated at 2.1 billion tonnes/year in 2020 and at 23 billion tonnes/year in 2024. Owing to a combination of economic and population growth, it is projected to increase by 56 per cent to 3.8 billion tonnes by 2050 if urgent action is not taken (UNEP, 2024).

The global share of uncontrolled MSW disposal (dumping and open burning; see Section 2.3.6) is projected to increase slightly, from 38 per cent in 2020 to 41 per cent by 2050. However, when projected MSW growth (Section 2.1) is factored in, this proportional increase will mean an almost two-fold increase in uncontrolled MSW, from 806 million tonnes in 2020 to 1.6 billion tonnes in 2050 (UNEP, 2024).

Key relevant UN convention / multilateral treaty

Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1989). At the time of writing, there were 187 parties to the Basel Convention (UN Treaty Collection 2019).

Basel Convention Amendments on Plastic Waste (2019) and E-waste (2021-2022).

UNEP's Global Framework on Chemicals and Waste (2023).

OECD waste policy updates (2023-2024)

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Solid waste generation, and in particular Municipal Solid Waste (MSW) is linearly related to GDP and waste management issues lead to the accumulation of waste. For example, the number of fast-growing middle-income countries, where waste management issues are especially prominent, is increasing. In 2020, 38 % of the MSW generated globally was uncontrolled. (UNEP, 2024). Some 2.7 billion people do not have their waste collected: 2 billion in rural areas and 700 million in urban areas. This amounts to 540 million tonnes of MSW, or around 27 % of the global total, not being collected (UNEP, 2024).

Impacts: Poor waste management (including ineffective collection and disposal) causes air, soil and water pollution (UN Environment, no date). Waste, including solid waste, influences the triple-planetary crisis of:

- Climate change: Transporting, processing and disposing of waste generates CO2 and other greenhouse gases and airborne pollutants that contribute to climate change.
- Biodiversity Loss: Indiscriminate waste disposal practices can introduce hazardous chemicals into soil, water bodies and the air, causing long-term, potentially irreversible damage to local flora and fauna, negatively impacting biodiversity, harming entire ecosystems, and entering the human food chain.
- Pollution: Between 400,000 and 1 million people die every year as a result of diseases related to mismanaged waste including diarrhoea, malaria, heart disease and cancer (Williams et al., 2019).

Solid waste creates favourable habitats for insects, rodents and other disease vectors and thereby increases the risk of diseases such as dengue, malaria and yellow fever (WHO, 2013; Sphere Association, 2018). In addition, communities may scavenge among solid waste, leading to increased cases of disease such as dysentery and exposure to other noxious or toxic substances. Meanwhile, indiscriminate dumping of waste can also block water courses causing flooding (WHO, 2013), causing contamination of the environment and impacting aquatic ecosystems, including the marine environment. People passing through solid waste-containing areas are exposed to the risk of injuries from broken glass, needles, etc. and exposure to contaminants. Waste has a demoralising impact on communities and may lower morale (WHO, 2013).

Multi-hazard Context: The figure below summarises common interactions between solid waste and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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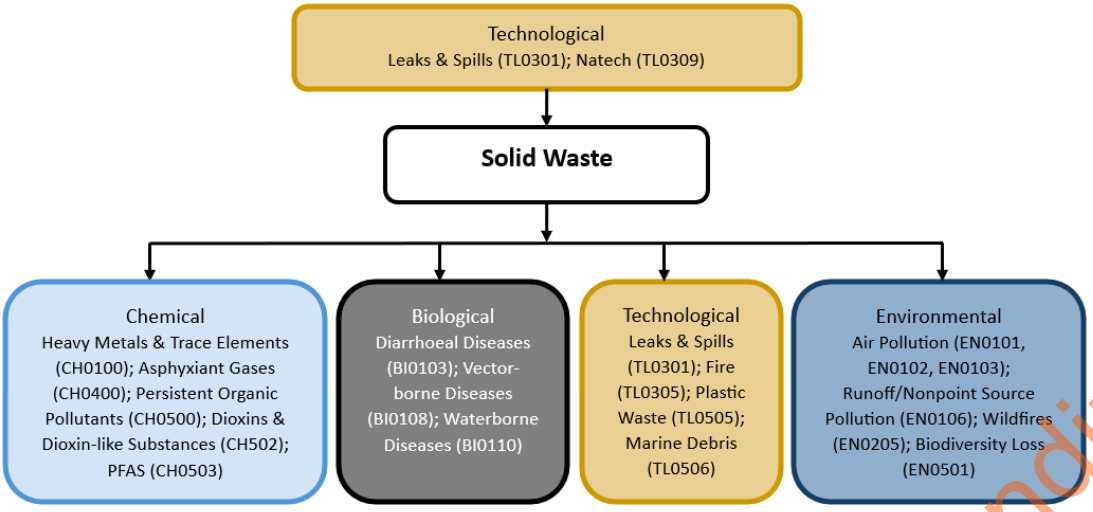

Monitoring: No information Available

Risk Management: There is an urgent need for both upstream measures to reduce resource use and waste generation, and downstream measures to reduce the environmental impacts of waste. Different sectors play different roles in delivering these measures (UNEP, 2024).

		Governments	Producers	Retailers	Waste management sector	Consumers
UPSTREAM	Prevent	✓	✓	-	-	✓
	Reduce	✓	✓	✓	-	✓
	Reuse	✓	✓	✓	-	✓
DOWNSTREAM	Recycle	✓	✓	-	✓	✓
	Recover energy, heat and control emissions	✓	-	-	✓	✓
	Dispose	✓	-	-	✓	✓

Table 1: The waste hierarchy and the role of different parts of society in controlling the generation and management of municipal waste (UNEP, 2024)

Reuse and recycling reduce demand for energy-intensive and environmentally damaging raw material extraction, enable waste to be valued as a resource, and prevent pollution from waste leaking into the environment. Reuse features more highly on the waste hierarchy as it does not involve energy-intensive processes in the way that recycling can (UNEP, 2024). However, recycling is not the ultimate goal of waste management: it is always better to reduce waste by preventing it in the first place, or reuse materials that would otherwise become waste, than to produce waste and then recycle it.

A circular economy is a model of production and consumption that involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products for as long as possible to extend the life cycle of the products, thereby reducing the extraction of new resources in favour of reusing existing ones (WHO, 2024).

Extended producer responsibility (EPR) is a policy approach that makes producers responsible for their products along the entire lifecycle, including at the post-consumer stage. By doing so, it helps achieve environmental goals such as recycling targets. At the same time, EPR generates funding from producers that help to pay for the collection, sorting and recycling of waste products, as well as generates detailed information on production, products, waste generation and treatment. The OECD's guidance identifies principles on the use of EPR, outlines possible options and details the benefits and trade-offs of different approaches. In this way, the OECD helps to harmonise the use of EPR schemes across countries (OECD, 2016).

Thermal waste-to-energy, also known as incineration with energy recovery, is a waste treatment method used in a

Preliminary – Corrections Pending

relatively small number of countries. Waste-to-energy represents linear resource use since materials that are combusted can never be recovered and used again. Although waste-to-energy technologies are widely used in some industrialised countries, questions persist concerning the adoption of these technologies. GHGs and other airborne pollutants emitted from combustion processes may also hinder countries' abilities to meet obligations related to their Nationally Determined Contributions (NDCs) and emission trading scheme allowances (UNEP, 2024).

The safe disposal of solid waste is critical for public health since solid waste poses a hazard in emergencies (WHO, 2013; 2024). The Sphere Handbook (Sphere Association, 2018) is the internationally recognised tool (but non-legally binding) in the field of humanitarian standards, including for solid waste management.

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Coordinating agency or organisation

Not identified.

Preliminary – Corrections Pending

TL0503 / TECHNOLOGICAL / Waste

Wastewater

Definition

Wastewater is regarded as a combination of one or more of the following materials: domestic effluent consisting of 'blackwater' (excreta, urine and faecal sludge, contaminants from pharmaceutical and personal care products) and 'greywater' (used water from washing and bathing); water from commercial establishments and institutions, including hospitals; industrial effluent, stormwater and other urban runoff; and agricultural, horticultural and aquaculture runoff (UNEP, 2023a).

Reference

UNEP, 2023a. Wastewater - Turning Problem to Solution. A UNEP Rapid Response Assessment. Nairobi. https://wedocs.unep.org/20.500.11822/43142 Accessed 20 January 2024

Preliminary – Corrections Pending

Annotations

Synonyms

Used water, Effluent.

Additional scientific description

Insufficient treatment of wastewater and faecal sludge spreads disease and is a driver of antimicrobial resistance (UNEP 2023b). Wastewater is also considered to contain increasing amounts and types of unregulated contaminants and organic compounds of emerging concern, such as human and veterinary antibiotics, and prescription and non-prescription drugs (UNEP, 2023a).

Demand for wastewater as a reliable source of water and nutrients for agriculture is growing under the pressures of population growth, urbanisation, increasing water scarcity and the effects of climate change (WHO, 2019). Wastewater can generate biogas, heat, and electricity. It can produce about five times more energy than is required for its treatment – enough to provide electricity for around half a billion people per year. The untapped potential for wastewater reuse is around 320 billion m^3 per year, with the potential to supply more than 10 times the current global desalination capacity. (UNEP, 2023a)

Metrics and numeric limits

WHO produces international norms on water quality and human health in the form of guidelines that are used as the basis for regulation and standard setting worldwide. The Guidelines for drinking-water quality promote the protection of public health by advocating for the development of locally relevant standards and regulations (health-based targets), adoption of preventive risk management approaches covering catchment to consumer (Water Safety Plans) and independent surveillance to ensure that Water Safety Plans are being implemented and effective and that national standards are being met. (WHO, no date).

Key relevant UN convention / multilateral treaty

Convention on the Protection and Use of Transboundary Watercourses and International Lakes also referred to as the Water Convention (1992). Although initially intended for the United Nations Economic Commission for Europe (UNECE) region, in 2016 the Water Convention allowed accession of all United Nations Member States worldwide. At the time of writing, there were43 parties to the Water Convention. Almost all countries sharing transboundary waters in the UNECE region are Parties to the Convention (UNECE, 2019).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Pollution from chemicals and waste is a major driver of biodiversity and ecosystem change, particularly in freshwater and marine habitats (Secretariats of the Basel, Rotterdam Stockholm Conventions, and the Minamata Convention on Mercury 2021; UNEP, 2023c; UNEP, 2023d)

Industrialisation without adherence to environmental standards and lack of wastewater management systems is a driver of contaminated wastewater. Globally, approximately 80% of all wastewater is discharged without adequate treatment (UNESCO, 2017). Wastewater critical infrastructure failure may also lead to the release of untreated wastewater into the environment. Uncontrolled dumpsites, which until the middle of the last century were the dominant disposal choice globally, pose ongoing risks to water quality, public health and the climate (Cristóbal et al., 2022)

Waste disposed of on land can cause long-term pollution of freshwater sources by pathogens, heavy metals, endocrine-disrupting chemicals and other hazardous compounds (Kuchelar & Sudarsan, 2022; Thives et al., 2022).

Floods, droughts, earthquakes, and landslides may affect the wastewater management system and lead to the release of wastewater into the environment (UNECE & WHO Europe, 2011).

It is estimated that 20 per cent of anthropogenic methane emissions are caused by the anaerobic decomposition of food and other organic materials left in landfills, open dumps and wastewater (UNEP & Climate and Clean Air Coalition, 2021)

Impacts: Wastewater accounts for about 1.57% of global greenhouse gas emissions, just below the climate harm caused by the global aviation industry (UNEP, 2023a). As of 2014, most cities were missing the appropriate infrastructure and resources to address wastewater management in an efficient and sustainable way (UNDESA 2014, cited in UN Water, no date). Urban areas with high population densities in low-income and lower-middle-income countries are considered particularly at risk (UNEP, 2016). Discharge of wastewater without adequate water treatment may have serious implications for health and well-being (UN Water, 2017).

In parallel, wastewater treatment plant operatives are exposed to a variety of hazardous chemical agents, within the effluents and the reagents used in water processing or generated during water treatment. These chemical agents may cause acute poisoning, chemical accidents (skin burns, injury to the eyes, etc.), damage to the respiratory system, allergies, dermatitis, and chronic diseases (ILO, 2012).

Several water-related diseases, including cholera and schistosomiasis, remain widespread across many developing countries, where only a very small fraction (in some cases less than 5%) of domestic and urban wastewater is treated prior to its release into the environment (UN WWAP, 2017). By 2030, the health and livelihoods of 4.8 billion people could be at risk if current water quality monitoring is not improved (UN-Water, 2024).

Demand for wastewater as a reliable source of water and nutrients for agriculture is growing under the pressures of population growth, urbanisation, increasing water scarcity and the effects of climate change (UNEP, 2023a).

Multi-hazard Context: The figure below summarises common interactions between wastewater and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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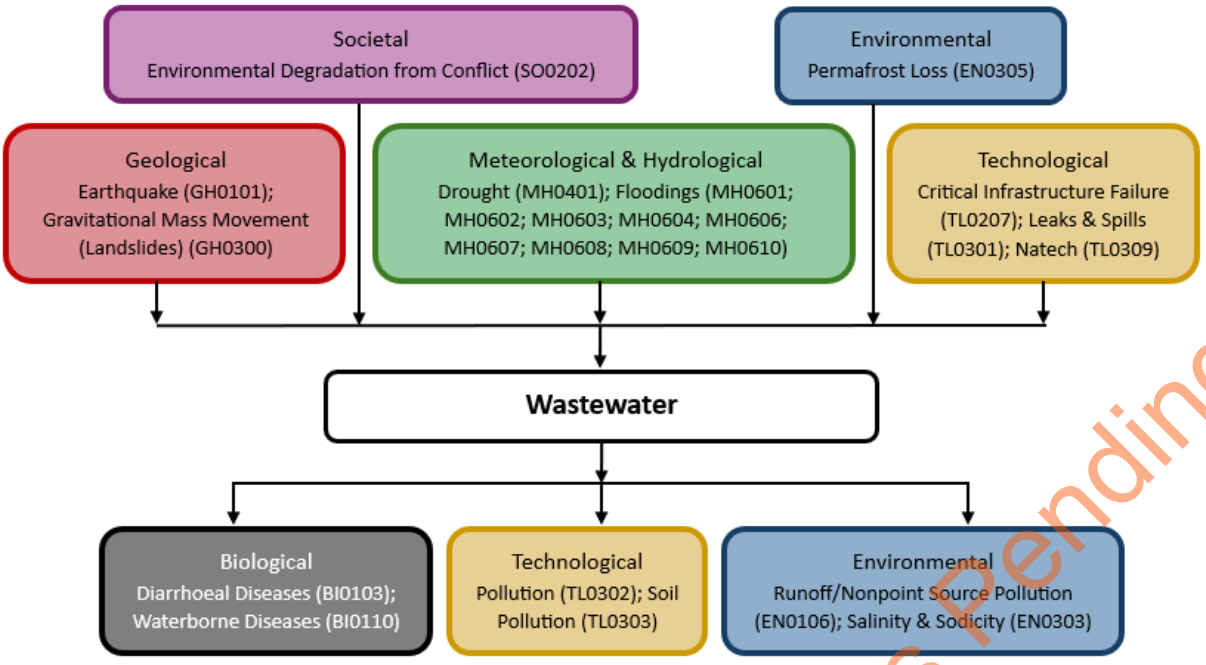

Monitoring: The section and the table below offer an overview of monitoring arsenic. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Private companies / public agencies managing wastewater facilities; Environment Protection Agencies, Health Agencies
How is the Hazard Observed/Monitored/Forecast?	Epidemiological surveillance of contamination by pathogens. For example, Digital-Water City's Early Warning System (EWS) is a tool able to identify the Occurrence of a contamination/hazard event in real-time or even beforehand during the production of reclaimed wastewater to improve the safeguard of public health and the environment. The EWS in the wastewater reuse sector has been designed to combine risk management with digitalization to ensure safe practices under automatized and continuous control. The EWS allows wastewater utilities to control, monitor, and share with stakeholders and users, data related to the safe reuse of treated water, maximizing the benefits of effective water reuse in agriculture. The system processes the available monitoring and operational data of the treatment plant within an interoperable platform and embeds machine learning algorithms for online data assessment, detection of outliers, failure analysis and prediction of contamination events at the outflow of the treatment plant. The system is connected with the local development of a risk management plan to ensure the safety and acceptability of water reuse practices (Digital-water.City, No date).

Risk Management:

UNEP contributes to the global efforts around wastewater surveillance for the environment and public health. Wastewater surveillance is a useful method to collect information and tackle diseases as well as land-based sources of pollution. Wastewater surveillance provides an important line of data to support the early detection of COVID-19 and other diseases. In addition, it also provides useful data to tackle land-based sources of pollution, maintain ecosystem services and protect freshwater and marine ecosystems. This trend is encouraging for the future of health systems and sound environmental management, but there is a need to expand this positive trend further and enhance the good practices and significant efforts to monitor and assess water quality. UNEP is managing a wastewater surveillance initiative with the goal of expanding wastewater surveillance programmes. The target of this initiative is Africa, where the goal is to help reduce wastewater and nutrient pollution, reduce risks for ecosystems and human health, and overall improve socio-economic and environmental conditions. The surveillance initiative involves all sub-regions of Africa and selected countries to advance capacity-building, transfer of knowledge and awareness raising through tailored training, awareness and communication material, and practical implementation of wastewater surveillance at selected airports and ports across Africa (UNEP, 2025).

As a research project supported by the European Union and Interreg, the Multi-hazard framework for water-related risk

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management (MUHA) project aimed at supporting Water Utilities, Civil Protection organizations, and Water Authorities to identify and mitigate hazardous events, contributing to water supply resiliency through Water Safety Plans (WSP). The project focused on four major hazards: floods, droughts, accidental pollution, and earthquakes. It sought to improve the methodology for developing WSP, a comprehensive risk assessment and risk management approach from catchment to consumer, ensuring the safety of drinking water supply. The project also aimed to harmonize Water Safety Plans and disaster response mechanisms at the transnational level. A risk assessment methodology was developed to evaluate the probability and severity of hazardous events, ensuring improved preparedness, response, and resilience (MUHA partnership, 2022).

Early warning for wastewater is primarily conducted for two purposes: epidemiological surveillance and environmental monitoring. For example, Digital-water City's Early Warning System is a tool able to identify the Occurrence of a contamination/hazard event in real-time or even beforehand during the production of reclaimed wastewater to improve the safeguard of public health and the environment. The EWS in the wastewater reuse sector has been designed to combine risk management with digitalization to ensure safe practices under automatized and continuous control. The EWS allows wastewater utilities to control, monitor, and share with stakeholders and users, data related to the safe reuse of treated water, maximizing the benefits of effective water reuse in agriculture. The system processes the available monitoring and operational data of the treatment plant within an interoperable platform and embeds machine learning algorithms for online data assessment, detection of outliers, failure analysis and prediction of contamination events at the outflow of the treatment plant. The system is connected with the local development of a risk management plan to ensure the safety and acceptability of water reuse practices (Digital-water.City, no date).

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Coordinating agency or organisation

Not identified.

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TL0504 / TECHNOLOGICAL / Waste

Hazardous Waste

Definitions

Hazardous waste is waste that has physical, chemical, or biological characteristics such that it requires special handling and disposal procedures to avoid negative health effects, adverse environmental effects or both (Joint UNEP/OCHA Environment Unit, 2011).

Reference

Joint UNEP/OCHA Environment Unit, 2011. Disaster Waste Management Guidelines. Annex X: Terminology. Joint United Nations Environment Programme (UNEP) / United Nations Office for the Coordination of Humanitarian Affairs (OCHA) Environment Unit. DisaterWM_guidelines.pdf Accessed 3 February 2025.

Annotations

Synonyms

Toxic waste, industrial waste, nuclear waste, contaminated materials, dangerous materials, pollution materials, poisonous waste. .

Additional scientific description

Hazardous waste is waste that, owing to its properties, poses an actual or potential hazard to the health of humans, other living organisms, or the environment (United Nations, 2016). Hazardous waste primarily comes from industrial activities, but it can also be present in households and commercial settings. In the USA, the EPA classifies hazardous waste into two main categories: listed waste and characteristic waste. Listed waste includes substances that the US EPA has identified as inherently hazardous due to their origin or composition. Characteristic waste refers to solid waste that displays one or more of four hazardous properties: ignitability, corrosivity, reactivity, or toxicity. If not managed correctly, these traits can pose risks to human health and the environment (US EPA, 2024).

Typical characteristics of hazardous waste include oxidising, explosive, flammable, irritant, corrosive, toxic, ecotoxic, radioactive, carcinogenic, infectious, and toxic for reproduction and/or mutagenic properties. Toxic wastes may produce toxic gases or liquids when in contact with water, air or acid which can result in the generation of additional hazardous substances following disposal. The term ‘hazardous’ relates to the situation and circumstances as well as to the properties of waste materials (Joint UNEP/OCHA Environment Unit, 2011). Different components of hazardous waste, including heavy metals, strong acids and bases are described in the information profile of chemical hazards (CH0100; CH300; CH500; CH0901).

Metrics and numeric limits

The UN, through various bodies like UNSD, UNEP, and UNECE, utilizes several metrics to track and manage hazardous waste. These metrics include quantifying the amount of hazardous waste generated, the proportion of hazardous waste treated, and the national recycling rate. Key indicators assess generation by weight (tonnes), per capita, and per square kilometre, as well as by type, including e-waste. Treatment is tracked by the type of treatment (recycling, incineration, landfilling), and the proportion of waste treated is calculated as a percentage of total generation.

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Key relevant UN convention / multilateral treaty

Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1989). At the time of writing, there were 187 parties to the Basel Convention (UN Treaty Collection, 2019).

International Conventions related to Harmonised System, Accord relatif au transport international des marchandises Dangereuses par Route (ADR), International Maritime Dangerous Goods, International Civil Aviation Organisation/International Air Transport Association and Globally Harmonised Systems codes

Stockholm Convention on Persistent organic Pollutants (POPs) Overview

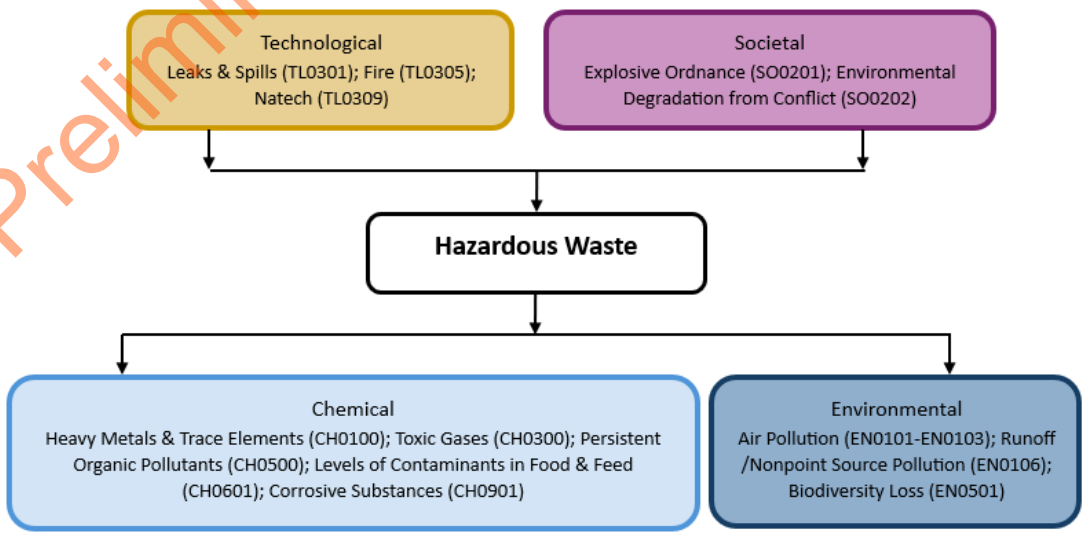
Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Hazardous waste can arise from diverse origins, including industrial manufacturing procedures, laboratories, hospitals, and even residences (e.g., specific cleansers, pesticides, or electronics) (Saleh et al., 2023). The risk of waste being mismanaged is heightened when waste management practices and regulations are weak, or where waste management is a low political priority and thus regulations are enforced incompletely or inconsistently. In such cases, the risks of waste being mismanaged are heightened by actors in the service chain seeking to reduce costs and maximise profits. This can occur even in countries with high-performing waste management sectors and extensive legislation (UNEP, 2024).

Impacts: Disposal and management of waste are worldwide problems. Toxic waste has the potential to pollute ecosystems, cause harm to wildlife, and disturb natural habitats (Saleh et al., 2023). Hazardous waste possesses the capability to infiltrate the ground and pollute soil and groundwater reserves, and cleaning polluted soil and water can be prohibitively expensive and arduous. Air pollution can occur depending on the nature of management of hazardous waste. If certain categories of dangerous waste are not properly managed, they can release noxious fumes and fine particles into the atmosphere (Saleh et al., 2023).

Hazardous waste also has impacts on human health. A recent systematic review of scientific literature on the link between hazardous waste and health indicated a limited causal relationship between hazardous waste and liver, bladder, breast and testis cancers and non-Hodgkin lymphoma (Fazzo et al., 2017). Among non-neoplastic diseases, asthma was found to be related to hazardous waste with limited evidence. Although links between hazardous waste and adverse birth outcomes were suspected, the evidence of a causal relationship was inadequate to support definitive conclusions. These data confirm that hazardous waste, if not suitably managed, might cause adverse health effects on populations living near the sites where they are dumped or processed. The contamination of different environmental matrices, including food, water, soil and air, represents a health risk for these populations (Fazzo et al., 2017).

Multi-hazard Context: The figure below summarises common interactions between hazardous waste and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



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Monitoring: The section and the table below offer an overview of monitoring for hazardous waste. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Academic studies, Environmental Monitoring Programs, International Policies and Conventions,
How is the Hazard Observed/Monitored/Forecast?	Monitoring of toxic waste deposition sites, monitoring of nearby aquifers

Risk Management: According to Agenda 21, the Rio Declaration on Environment and Development, adopted by more than 178 governments at the United Nations Conference on Environment and Development held in Rio de Janeiro, Brazil, 3-14 June 1992, it was recognised that to address effective control of the generation, storage, treatment, recycling and reuse, transport, recovery and disposal of hazardous wastes is "of paramount importance for proper health, environmental protection and natural resource management, and sustainable development" (United Nations, 1992: Chapter 20). The development of an Early Warning System (EWS) for hazardous chemicals is a pivotal element in safeguarding public health and environmental quality. The EWS aims to proactively detect and assess potential risks caused by hazardous chemicals on a European level, serving as a rapid-response tool to enable mitigation actions and protect communities. In this effort, to identify chemical hazards, the detection of risks is intrinsically linked to the biological effects that these chemicals can cause. Consequently, to accurately estimate chemical risks, the inclusion of methods capable of identifying toxicity effects, known as effect-based methods, becomes indispensable (PARC, 2023).

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Coordinating agency or organisation

United Nations Environment Programme

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TL0505 / TECHNOLOGICAL / Waste

Plastic Waste

Definition

Plastic Waste is defined as any discarded plastic (organic, or synthetic, material derived from polymers, resins or cellulose) generated by any industrial process, or by consumers. (Source: GEMET/APD).

Reference

Montevideo Environmental Law Programme. https://leap.unep.org/en/knowledge/glossary/plastic-waste Accessed 11 February 2025

Annotations

Synonyms

Plastic pollution, Plastic debris, Plastic litter, Plastic marine litter, Plastic trash.

Additional scientific description

Plastic is a lightweight, hygienic and resistant material which can be moulded in a variety of ways and used in a wide range of applications. Unlike metals, plastics do not rust or corrode. Most plastics do not biodegrade, but instead photodegrade, a process in which exposure to environmental factors, including sunlight, breaks them down into smaller fragments, eventually forming microplastics, which can persist in the environment for long periods. (UNEP, 2018).

The 14th Meeting of the Conference of the Parties to the Basel Convention defined categories of wastes requiring special consideration (European Commission, 2019). This includes:

- Plastic waste, including mixtures of such waste, with the exception of the following: plastic waste that is hazardous waste pursuant to paragraph 1 (a) of Article 18; plastic waste listed below, provided it is destined for recycling in an environmentally sound manner and almost free from contamination and other types of wastes; and plastic waste almost exclusively consisting of one non-halogenated polymer, including but not limited to the following polymers: polyethylene (PE), polypropylene (PP), polystyrene (PS), acrylonitrile butadiene styrene (ABS), polyethylene terephthalate (PET), polycarbonates (PC), polyurethane (PUR) and polyethers.
- Plastic waste almost exclusively consisting of one cured resin or condensation product, including but not limited to the following resins: urea formaldehyde resins; phenol formaldehyde resins; melamine formaldehyde resins; epoxy resins; and alkyd resins.

Plastic waste almost exclusively consisting of one of the following fluorinated polymers: perfluoroethylene/ propylene (FEP); perfluoroalkoxy alkanes; tetrafluoroethylene/ perfluoroalkyl vinyl ether (PFA); tetrafluoroethylene/ perfluoromethyl vinyl ether (MFA); polyvinylfluoride (PVF); polyvinylidenefluoride (PVDF); and mixtures of plastic waste, consisting of polyethylene (PE), polypropylene (PP) and/or polyethylene terephthalate (PET), provided they are destined for separate recycling of each material and in an environmentally sound manner and almost free from contamination and other types of wastes. Most plastics are usually a blend of polymers and additives (e.g., stabilisers such as lead stabilisers and cadmium stabilisers; plasticisers such as phthalates; flame retardants such as antimony oxides, phosphatases, brominated flame retardants and medium-chain chlorinated paraffins). The elements most commonly found in plastics are carbon, hydrogen, nitrogen, oxygen, chlorine, fluorine and bromine. Some of these elements are hazardous when uncombined but become inert when incorporated into an organic polymer (UNEP, 2023a, 2023b).

The composition of plastic waste does not only depend on the intrinsic composition of the different plastics

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included, but also on impurities or contaminants. These impurities may arise from the various applications of the plastic, as well as the processes of waste generation and collection. For instance, plastic food packaging may contain food residues, films used in agriculture may contain high percentages of soil and pesticide, and plastic waste from cables may contain residual metals such as copper or aluminium. These contaminants can complicate the recycling and disposal of plastic waste, as they introduce additional challenges for ensuring environmentally sound management. The presence of these impurities highlights the need for effective separation, cleaning, and sorting technologies to improve recycling efficiency and reduce contamination risks (UNEP, 2018). COVID-19 increased single-use plastic waste, though plastics use fell overall. The lockdowns and decline in economic activity during 2020 reduced plastics use by 2.2% from 2019 levels. However, the increase in the use of protective personal equipment and single-use plastics has exacerbated plastic littering.

Plastic pollution is defined broadly as the negative effects and emissions resulting from the production and consumption of plastic materials and products across their entire life cycle. This definition includes plastic waste that is mismanaged (e.g. open-burned and dumped in uncontrolled dumpsites) and leakage and accumulation of plastic objects and particles that can adversely affect humans and the living and non-living environment (UNEP, 2023b).

Over 13,000 substances have so far been associated with plastics, either known for use in plastic production or detected in plastic materials. Chemicals of concern can be released from plastic along its entire life cycle, during not only the extraction of raw materials, production of polymers and manufacture of plastic products, but also the use of plastic products and at the end of their life, particularly when waste is not properly managed, finding their way to the air, water and soils. Some chemicals can pose significant challenges to technological solutions to plastics recycling and material circularity (UNEP, 2023a).

Sources of plastic waste can also be categorized based on applications (e.g., bottles/caps/lids: 14.9 %, PET bottles: 12.5 %, supermarket bags/retail bags: 9.3 %, food bags: 6.5 %, food containers: 2.1 %, etc.) and origin (e.g., municipal solid waste and agro-industrial waste) (Nayanathara et al., 2024). Waste requires a consideration of local circumstances and of both the intrinsic composition of plastic and potential contamination. The presence of impurities and contaminants in the plastics may influence the options for managing the waste in an environmentally sound manner and should be addressed appropriately. Contaminated plastic wastes may be a major or minor hazard depending on the contaminant (UNEP, 2023a).

Metrics and Numerical Limits

Globally, the annual production of plastics has doubled, soaring from 234 million tonnes (Mt) in 2000 to 460 Mt in 2019. Plastic waste has more than doubled, from 156 Mt in 2000 to 353 Mt in 2019. After considering losses during recycling, only 9% of plastic waste was ultimately recycled, while 19% was incinerated and almost 50% went to sanitary landfills. The remaining 22% was disposed of in uncontrolled dumpsites, burned in open pits or leaked into the environment. In 2019 alone, 6.1 Mt of plastic waste leaked into rivers, lakes and the ocean. The build-up of plastics in rivers implies that leakage into the ocean will continue for decades to come even if mismanaged plastic waste was significantly reduced. Furthermore, cleaning up these plastics is becoming more difficult and costly as plastics fragment into ever smaller particles (OECD, 2022). Every minute, the equivalent of one garbage truck full of plastic is dumped into the ocean (WEF, 2016).

Key relevant UN convention / multilateral treaty

Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1989). At the time of writing, there were 187 parties to the Basel Convention (UN Treaty Collection, 2019). At its 14th meeting, the Conference of the Parties to the Basel Convention adopted decision BC-14/12 by which it amended Annexes II, VIII and IX to the Convention with the objectives of enhancing the control of the transboundary movements of plastic waste and clarifying the scope of the Convention as it applies to such waste (European Commission, 2019).

The following new entries to the Basel Convention Plastic Waste Amendment became effective on 1 January 2021:

- Annex II, new entry Y48: covers plastic waste, including mixtures of with various exceptions listed thereunder, making them subject to the prior informed consent (PIC) procedure.
- Annex VIII, new entry A3210: clarifies the scope of plastic waste presumed to be hazardous and therefore subject to the PIC procedure.
- Annex IX, new entry B3011 replacing existing entry B3010: clarifies the types of plastic waste that are presumed not to be hazardous and, as such, not subject to the PIC procedure. The waste listed in entry B3011 includes: a

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group of cured resins, non-halogenated and fluorinated polymers, provided the waste is destined for recycling in an environmentally sound manner and almost free from contamination and other types of wastes; mixtures of plastic wastes consisting of PE, PP and PET provided they are destined for separate recycling of each material and in an environmentally sound manner, and almost free from contamination and other types of waste.

Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (IMO, 2020), or 'London Convention' for short. This is one of the first global conventions to protect the marine environment from human activities and has been in force since 1975. Its objective is to promote the effective control of all sources of marine pollution and to take all practicable steps to prevent pollution of the sea by dumping of wastes and other matter. Currently, 87 States are Parties to this Convention.

Stockholm Convention on Persistent Organic Pollutants (POPs) (2004)

Examples of hazard drivers, impacts, and risk management

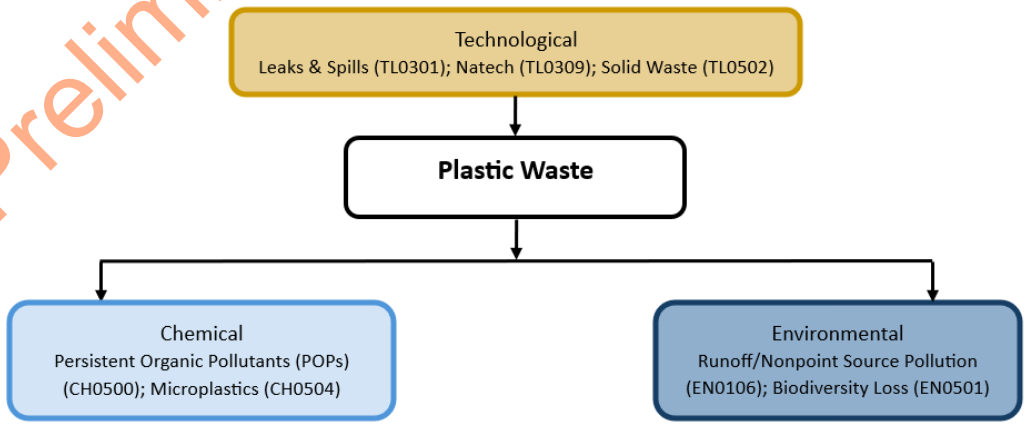
Hazard Drivers: Overconsumption of plastic, lack of regulations and population increase are among the drivers of plastic production plastic waste (OECD, 2022).

Impacts: Plastic pollution, including plastic waste, harms wildlife and damages ecosystems (UNEP, no date) and is responsible for vast economic losses in the tourism, fishing and shipping industries. Worldwide, the total damage to the world's marine ecosystem due to plastic waste is estimated to total at least $13 billion per year (Independent Group of Scientists, 2019). As well as harm to wildlife and ecosystems, many plastics may be chemically harmful in other contexts because they are themselves potentially toxic, contain additives or because they absorb other pollutants (Rochman et al., 2013).

The human health risk from microplastics in drinking water is a function of both hazard and exposure. Potential hazards associated with microplastics come in three forms: the particles themselves which present a physical hazard, chemicals (unbound monomers, additives, and sorbed chemicals from the environment), and microorganisms that may attach and colonize on microplastics, known as biofilms. Based on the limited evidence available, chemicals and microbial pathogens associated with microplastics in drinking-water pose a low concern for human health. Although there is insufficient information to draw firm conclusions on the toxicity of nanoparticles, no reliable information suggests it is a concern (WHO,2019).

WHO,(2019) and SAPEA (2019) identified that there is very little published data is available regarding either exposure to, or the toxicity of microplastics and nanoplastics in humans, The reports acknowledge the current challenges facing scientists attempting to gather robust information and recommend proceeding to fill knowledge gaps. The SAPEA report states on p. 116 that '*the absence of evidence of microplastics risks currently does not allow one to conclude that risk is either present or absent with sufficient certainty*' (SAPEA, 2019).

Multi-hazard Context: The figure below summarises common interactions between plastic waste and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring plastic waste. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or

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regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Academic studies, Environmental Monitoring Programs, International Policies and Conventions,
How is the Hazard Observed/Monitored/Forecast?	Marine and Coastal Monitoring, Remote Sensing and Satellite Imaging, Citizen Science and Community-Based Observations, Forecasting Tools and Models

Risk Management: Plastic waste recycling faces technical, economic and structural issues that are still to be overcome globally (UNEP, 2023b). Recycling of plastic waste can be supported with legal and economic instruments (UNEP, 2023b). To reduce plastic pollution, it is of critical importance to improve the state of solid waste collection services, strengthen the recycling industry and ensure safe disposal of waste to controlled landfills (UNEP, 2018).

As part of water safety planning, water suppliers should ensure that control measures are effective and should optimise water treatment processes for particle removal and microbial safety, which will incidentally improve the removal of microplastic particles. The report also stated that measures should be taken to better manage plastics and reduce the use of plastics where possible, to minimise plastic and microplastic pollution despite the low human health risk posed by exposure to microplastics in drinking-water, as such actions can confer other benefits to the environment and human well-being (WHO, 2019).

Addressing the issue of plastics waste in a multi-hazard context requires an integrated approach that accounts for the interactions between environmental, anthropogenic, and socio-economic factors. Effective management strategies must include regulatory frameworks, technological advancements, public awareness campaigns, and global cooperation to reduce the environmental and health impacts of plastic waste (Kaza et al., 2018; Da Costa et al., 2020).

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Coordinating agency or organisation

Not identified.

Preliminary – Corrections Pending

TL0506 / TECHNOLOGICAL / Waste

Marine Debris

Definition

Marine debris is any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment. Marine litter consists of items that have been made or used by people and deliberately discarded into the sea or rivers or on beaches; brought indirectly to the sea with rivers, sewage, stormwater or winds; or accidentally lost, including material lost at sea in bad weather (adapted from UN Environment, no date and NOAA, no date).

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Preliminary – Corrections Pending

Annotations

Synonyms

Microplastics, Nanoparticles.

Additional scientific description

Marine debris originates from many sources and causes a wide spectrum of environmental, economic, safety, health and cultural impacts. The very slow rate of degradation of most marine litter items, mainly plastics, together with the ever-growing quantity of debris disposed of, is leading to a gradual increase in marine litter found at sea and on the shores (United Nations, 2017).

Marine debris is present in all marine habitats, from densely populated regions to remote areas far from human activities, from beaches and shallow waters to deep ocean trenches (Wang et al., 2016). The average density of marine debris is estimated to vary from 13,000 to 18,000 pieces per square kilometre (UNEP, 2017). However, data on plastic accumulation in the North Atlantic and Caribbean from 1986 to 2008 showed that the highest concentrations (more than 200,000 pieces per square kilometre) occurred in the convergence zones between two or more ocean currents (Law et al., 2010). Computer model simulations, based on data from about 12,000 satellite-tracked floats deployed since the early 1990s as part of the Global Ocean Drifter Program, confirm that debris will be transported by ocean currents and will tend to accumulate in a limited number of subtropical convergence zones or gyres (Wang et al., 2016).

Marine debris takes many forms, including derelict fishing gear and vessels, abandoned recreational equipment, and discarded consumer plastics, metals, rubber, paper, and textiles. Plastics are by far the most prevalent debris item recorded, contributing an estimated 60% to 80% of all marine debris. Plastic debris continues to accumulate in the marine environment (see Microplastics HIP – CH0504). The density of microplastics within the North Pacific Central Gyre has increased by two orders of magnitude in the past four decades. Marine debris commonly stems from shoreline and recreational activities, commercial shipping and fishing, and dumping at sea. The majority of marine debris (approximately 80%) entering the sea is considered to originate from land-based sources.

Nanoparticles are a form of marine debris, the significance of which is only now emerging. They are minuscule particles with

dimensions of 1 to 100 nanometres (a nanometre is one millionth of a millimetre). A large proportion of the nanoparticles found in the ocean are of natural origin. It is the anthropogenic nanoparticles that are of concern. Those originate from two sources: from nanoparticles deliberately created for use in various industrial processes and cosmetics and from the breakdown of plastics in marine debris, fragments of artificial fabrics discharged in urban wastewater, and leaching from land-based waste sites. Recent research has highlighted the potential environmental impacts of plastic nanoparticles: they appear to reduce primary production and uptake of food by zooplankton and filter-feeders (United Nations, 2017).

Metrics and numeric limits

Not available.

Key relevant UN convention / multilateral treaty

Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (IMO, 2019).

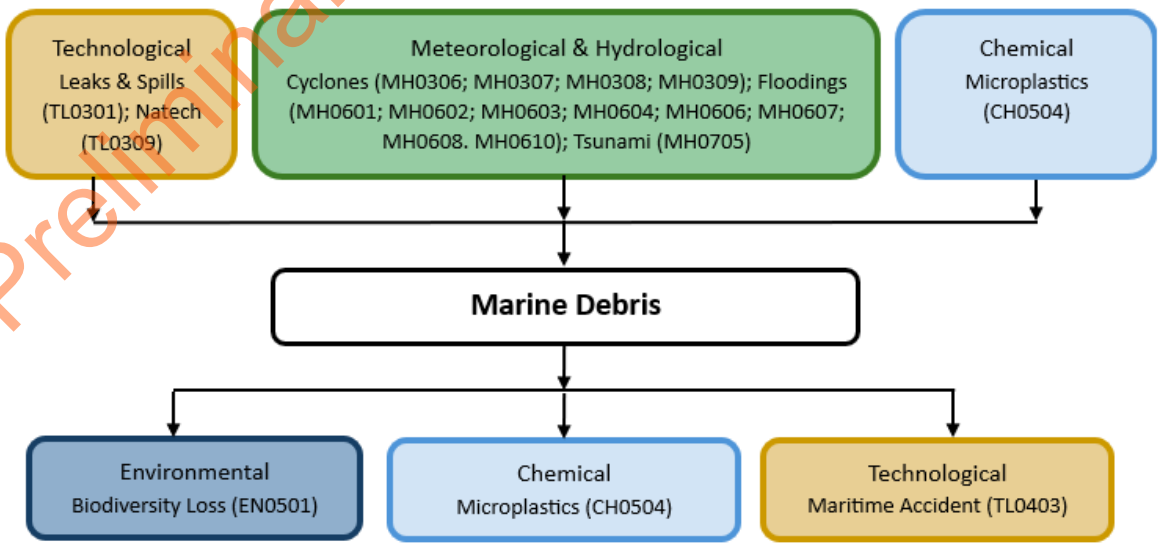
Examples of hazard drivers, impacts, and risk management

Hazard drivers: Natural hazards such as cyclones, floods, landslides and tsunamis, along with human-induced accidents, can significantly increase the influx of both natural and artificial debris into marine environments. According to the Japan Ministry of the Environment (2012), the 2011 tsunami in Japan released approximately 5 million tons of debris into the ocean within hours. Of this, 3.5 million tons settled on the seafloor, causing severe damage to the benthic ecosystem. Additionally, the radioactive spill from the Fukushima nuclear disaster had devastating effects on the local fishing industry. The remaining 1.5 million tons—equivalent to nearly a full year's worth of land-based plastic debris input for the entire North Pacific—became floating debris, with portions drifting toward North America and Hawai'i. This included four 20-metre floating docks, around 1,000 vessels (Maximenko et al., 2018), and other large objects that posed hazards to navigation and remote coastlines. Many nearshore mariculture farms were also dislodged, resulting in a significant increase in floating debris.

Impacts: Marine debris can result in economic losses, habitat damage (including fragile coral reefs), hazards to shipping resulting in costly vessel damage and loss, transport of potentially invasive species that may have devastating impacts on ecosystems, and wildlife injury, illness, and death (NOAA, no date).

Marine debris can affect a wide range of marine life, from small microorganisms to humpback whales. Animals may inadvertently eat debris or become entangled in it. For instance, plastic bags are a common threat to sea turtles, which often mistake them for jellyfish, a common food item. Marine debris also affects other species, such as the endangered Hawaiian monk seal, where one death caused by marine debris is a huge loss (NOAA, no date).

Multi-hazard Context: The figure below summarises common interactions between marine debris and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: No information available

Risk Management: Persistent microplastic waste, originating from various sources and carried by rivers into the ocean, has caused significant biological, ecological, and chemical impacts on marine ecosystems and is recognized as a global issue. Over the past decade, numerous studies have employed remote sensing technologies to detect, monitor, and track marine plastic

Preliminary – Corrections Pending

debris in both coastal and open ocean environments (Waqas et al, 2023). For example, the Integrated Marine Debris Observing System (IMDOS) aims to guide and coordinate a globally sustained monitoring system for marine debris, bridging knowledge gaps and meeting the diverse needs of stakeholders by providing reliable data and information (IOCCP, No date).

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Coordinating agency or organisation

United Nations Environment Programme

Preliminary – Corrections Pending

TL0507 / TECHNOLOGICAL / Waste

Electronic Waste (E-Waste)

Definition

Electrical and electronic waste, or E-waste, refers to electrical or electronic equipment that is waste, including all components, sub-assemblies and consumables that are part of the equipment at the time the equipment becomes waste (UNEP, 2019a).

Reference

UNEP, 2019a. Technical guidelines on transboundary movements of electrical and electronic waste and used electrical and electronic equipment, in particular regarding the distinction between waste and non-waste under the Basel Convention. (Version of 10 May 2019). United Nations Environment Programme (UNEP). www.basel.int/Implementation/TechnicalMatters/DevelopmentofTechnicalGuidelines/TechnicalGuidelines/tabid/8025/Default.aspx Accessed 11 February 2025.

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Annotations

Synonyms

Waste Electrical and Electronic Equipment (WEEE), E-scrap.

Additional scientific description

Electrical and electronic waste is classified both as hazardous waste and non-hazardous waste, according to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (UNEP, no date a). It is categorised as hazardous waste when it belongs to any category in Annex I of the Basel Convention unless it does not possess any of the hazardous characteristics included in Annex III to the Convention. For example, e-waste is classified as hazardous waste when it contains toxic substances such as mercury, lead and brominated flame retardants (Basel Convention, 2020).

Besides containing recyclable and recoverable metals and materials such as gold, copper, nickel, silver, rare earths and materials of strategic importance such as indium and palladium, e-waste can contain up to 60 different elements from the period table, including hazardous chemicals, of which some are persistent organic pollutants (POPs) and dioxins listed under the Stockholm Convention on Persistent Organic Pollutants (PACE, 2019).

The distinction between waste and non-waste equipment is important. Some countries may consider used equipment destined for failure analysis, repair, or refurbishment as waste, while others may not. This distinction can affect how the material is classified and regulated.
https://www.basel.int/Implementation/Ewaste/EwasteAmendments/EwasteAmendmentsFAQs/tabid/10107/Default.aspx

Metrics and numeric limits

Classification of e-waste that can inform the metrics is now provided in Annex II (Y49 for non-hazardous e-waste) and Annex VIII (A1181 for hazardous e-waste) under the Basel Convention. The previous distinctions between hazardous and non-hazardous e-waste in Annexes VIII and IX (e.g., A1180 and B1110) are no longer applicable.
https://www.basel.int/Implementation/Ewaste/EwasteAmendments/EwasteAmendmentsFAQs/tabid/10107/Default.aspx

https://www.basel.int/Implementation/PublicAwareness/NewsFeatures/Ewastetechnicalguidelines/tabid/5122/Default.aspx

A record 53.6 million metric tonnes (Mt) of electronic waste was generated worldwide in 2019, up 21 per cent in just five years. The new report (Global e-waste Monitor, 2024) also predicts global e-waste will reach 82 Mt by 2030. A record 62 million tonnes (Mt) of e-waste was produced in 2022, up 82% from 2010. This amount is projected to rise by another 32%, reaching 82 million tonnes by 2030. The annual generation of e-waste is increasing by 2.6 million tonnes per year. https://ewastemonitor.info/the-

global-e-waste-monitor-2024/

Key relevant UN convention / multilateral treaty

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, adopted in 1989, is a key multilateral environmental agreement. As of January 1, 2024, it has 191 Parties. The Convention has undergone significant amendments since its adoption, with the most recent changes related to e-waste management set to take effect on January 1, 2025 (Basel Convention Secretariat, 2024).

https://www.basel.int/countries/statusofratifications/tabid/1341/default.aspx

https://www.basel.int/theconvention/overview/textoftheconvention/tabid/1275/default.aspx

https://www.unep.org/resources/report/basel-convention-control-transboundary-movements-hazardous-wastes

Stockholm Convention on Persistent Organic Pollutants (POPs)

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: While e-waste is one of the fastest-growing hazardous waste streams globally (UNEP, 2007a; PACE, 2019), the findings from the Global E-Waste Monitor 2017 highlighted the low rate of electronic waste recycled globally (Baldé et al., 2017). By 2016, the world generated 44.7 million metric tonnes of e-waste and only around 20% was recycled through appropriate channels (Baldé et al., 2017). The World Health Organization reported in 2020 that global e-waste is surging and is up 21% in 5 years with a record 53.6 million tonnes of e-waste produced globally in 2019 – the weight of 350 cruise ships the size of the Queen Mary 2; USD 57 billion in gold and other components discarded – mostly dumped or burned (WHO, 2020).

E-waste dumping and open burning is driven and exacerbated by such factors as lack of a formal infrastructure ensuring proper decontamination, dismantling, recycling, recovery of items of economic value, disposal of electronic waste fractions, such as through open burning, poor incineration and use of acid baths for metals extraction, landfilling; lack of environmental protection measures and treatment standards; lack of policies, legislation or insufficient implementation and enforcement of relevant legislation; and illegal export and dumping (Baldé et al., 2017).

E-waste dumping and open burning are driven by multiple factors, as highlighted in the Global E-waste Monitor 2024 and recent WHO reports. These include:

1. Insufficient formal infrastructure for proper e-waste management, including decontamination, dismantling, and recycling facilities.
2. Lack of environmentally sound disposal methods, leading to harmful practices such as open burning, improper incineration, and use of acid baths for metal extraction.
3. Inadequate environmental protection measures and treatment standards.
4. Weak or poorly enforced policies and legislation regarding e-waste management.
5. Illegal export and dumping of e-waste, often from developed to developing countries.
6. Limited awareness of the health and environmental risks associated with improper e-waste handling.
7. Economic pressures driving informal recycling practices in many regions.

These factors contribute to a global situation where, as of 2022, only 22.3% of the 62 million tonnes of e-waste generated was documented as being properly collected and recycled. The remaining e-waste often ends up in landfills or is handled through informal and potentially hazardous recycling methods, posing significant risks to human health and the environment. https://ewastemonitor.info/the-global-e-waste-monitor-2024/; https://www.who.int/publications/i/item/WHO-HEP-ECH-CHE-21-01; https://www.who.int/news-room/fact-sheets/detail/electronic-waste-(e-waste)

Impacts: This rapid growth in e-waste poses significant risks to human health and the environment. Children and pregnant women are particularly vulnerable to the toxic chemicals in e-waste. Exposure can lead to adverse neonatal outcomes, neurodevelopmental issues, changes in lung function, DNA damage, impaired thyroid function, and increased risk of chronic diseases later in life, such as cancer and cardiovascular disease. https://www.who.int/news/item/15-06-2021-soaring-e-waste-affects-the-health-of-millions-of-children-who-warns

Electrical and E-waste can cause severe damage to human health through exposure to hazardous elements and informal recycling and the environment (Forti et al., 2018), through direct and indirect human exposure and through contamination of soil, groundwater and air. Several health studies suggest effects from exposure to electrical and electronic waste, including adverse perinatal and neonatal outcomes and changes in behavioural and mental health disturbances (Grant et al., 2013; UNEP, 2018, cited in United Nations, 2019; PACE, 2019). Many POPs in electronic waste are also considered to be endocrine-disrupting chemicals (Grant et al., 2013).

The environmental impacts of the first e-products (mainly energy-intensive household appliances) with longer lifetimes were

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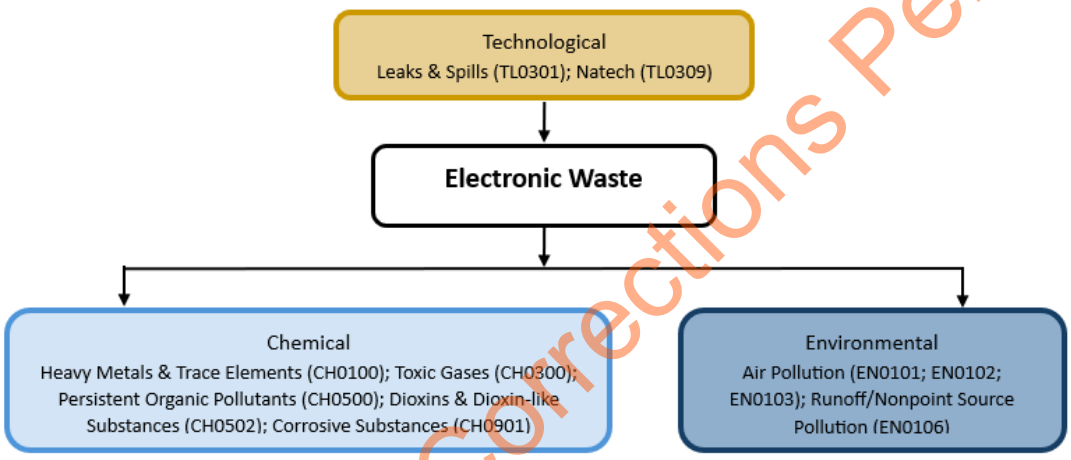
mostly linked to the 'use' phase of the products. But as e-products become more advanced, and use an increasing number of resources, the environmental impacts are now shifting from 'use' to the 'production' and 'material extraction' stages. Given the challenges of resource extraction, manufacturing and EoL resource recovery, energy use is no longer the most crucial factor in the lifecycle of modern products such as smartphones. This translates into the use of more land, water, and energy, as well as other socioeconomic issues including health hazards, human rights, and conflicts linked to the mining process. The chemicals used in manufacturing can also leave a long trail of toxicity. For example, fluorinated greenhouse gases, used in manufacturing LCD flat-panel displays, involve chemicals with atmospheric lifetimes beyond 3,000 years and thousands of times more global warming potential than CO_2. Manufacturing chips and semiconductors uses a variety of chemicals, including volatile organic compounds. The lack of guiding policies and proper processing infrastructure, rudimentary e-waste recycling practices can lead to serious damage. The infamous e-waste 'recycling' sites in Agbogbloshie, Ghana and Guiyu, China are extreme examples of improper e-waste recycling that results in severe air, water, and soil pollution (UNEP, 2019)

Multi-hazard Context: The figure below summarises common interactions between electronic waste and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: No Information Available

Risk Management: Technologies or technical interventions are vital for the WEEE/E-waste management chain to maximize material recovery and minimize the risks. Technical interventions for the collection and transportation of WEEE/E-waste are commonly known as treatment channels and infrastructure. Technical interventions for the treatment of WEEE/E-waste are generally known as treatment technologies. Environmental impacts of treatment technologies (UNEP, 2007b).

Countries that already have WEEE/E-waste regulations often encounter difficulties when putting the regulations into practice. The difficulties are derived from a lack of mechanisms in the flow of WEEE/E-waste in the WEEE/E-waste life cycle. They feel the need to plan and adopt the most effective collection and transport systems to accompany the regulatory systems (UNEP, 2012).

The solution to the e-waste problem is not simply the banning of transboundary movements of e-waste, as domestic generation accounts for a significant proportion of e-waste in all countries. Fundamental to a sustainable solution will be tackling the fact that current practices and illegal trade provide economic stimulus. It is important to recognize local and regional contexts and the social implications of the issue; implementing a high-tech, capital-intensive recycling process will not be appropriate in every country or region. Effective regulation must be combined with incentives for recyclers in the informal sector not to engage in destructive processes. Cheap, safe, and simple processing methods for introduction into the informal sector are currently lacking; hence, it is necessary to create a financial incentive for recyclers operating in the informal sector to deliver recovered parts to central collection sites rather than process them themselves. Multidisciplinary solutions are vital in addition to technical solutions, as is addressing the underlying social inequities inherent in the e-waste business (Sydnes; 2021).

Electronic Waste (e-waste) early warning systems are innovative solutions designed to improve the management and monitoring of electronic waste. Additionally, Early Warning System is a tool that helps companies or relevant organizations predict and monitor in advance whether they are meeting their e-waste collection targets. Based on various data such as past sales figures, the number of households, electricity consumption, income inequality (e.g., the GINI coefficient), and population density, an Artificial Neural Network (ANN) model forecasts the amount of e-waste that will be collected in the future. The forecasted collection amount is then compared with the collection targets set by environmental regulations. If it is expected that the target will not be met, the discrepancy is flagged as a "warning" signal. Once a warning signal is triggered, the company or organization can take measures to improve its collection system or implement additional actions to meet the target (Bolat et al., 2019b).

Preliminary – Corrections Pending

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Coordinating agency or organisation

Not identified.

Preliminary – Corrections Pending

TL0508 / TECHNOLOGICAL / Waste

Health-care Waste

Definition

Health-care waste is a by-product of health care that includes sharps, non-sharp blood-contaminated items, blood, body parts and tissues, chemicals, pharmaceuticals and radioactive materials. Safe management of health-care waste protects health-care workers, waste handlers, patients and their families and the community from preventable infections, toxic effects and injuries (adapted from WHO, no date, and WHO, 2017).

Reference

WHO, no date. Healthcare waste. World Health Organization (WHO) https://www.who.int/teams/environment-climate-change-and-health/water-sanitation-and-health-(wash)/health-care-facilities/health-care-waste Accessed 18 March 2025

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Annotations

Synonyms

medical waste, clinical waste, regulated medical waste, hospital waste

Additional scientific description

Health-care activities protect and restore health and save lives. The main sources of medical waste are hospitals, clinics, laboratories, blood banks and mortuaries. Whereas physician's offices, dental clinics, pharmacies, home-based health-care and so on, generate health-care waste but in smaller amounts (UNGA, 2011). Of the total amount of waste generated by health-care activities, about 85% is general, non-hazardous waste comparable to domestic waste. The remaining 15% is considered hazardous material that may be infectious, chemical or radioactive. Measures to ensure the safe and environmentally sound management of health-care wastes can prevent adverse health and environmental impacts from such waste including the unintended release of chemical or biological hazards (WHO, 2024).

WHO (2024) identifies waste and by-products as covering a diverse range of materials, including:

- infectious waste: waste known or suspected to contain pathogens and pose a risk of disease transmission, e.g. waste and waste water contaminated with blood and other body fluids, including highly infectious waste such as laboratory cultures and microbiological stocks; and waste including excreta and other materials that have been in contact with patients infected with highly infectious diseases in isolation wards;
- pathological waste: human tissues, organs or fluids, body parts, foetuses, unused blood products and contaminated animal carcasses;
- sharps waste: used or unused sharps, e.g. hypodermic, intravenous or other needles; auto-disable syringes; syringes with attached needles; infusion sets; scalpels; pipettes; knives; blades; broken glass;
- chemical waste: for example, solvents and reagents used for laboratory preparations, disinfectants, sterilants and heavy metals contained in medical devices (e.g. mercury in broken thermometers) and batteries;

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- pharmaceutical and cytotoxic waste: pharmaceuticals that are expired or no longer needed; items contaminated by, or containing, pharmaceuticals. Cytotoxic waste containing substances with genotoxic properties, e.g. waste containing cytostatic drugs (often used in cancer therapy); genotoxic chemicals;
- radioactive waste: such as products contaminated by radionuclides including radioactive diagnostic material or radiotherapeutic materials; and
- non-hazardous or general waste: waste that does not pose any particular biological, chemical, radioactive or physical hazard (WHO, 2024).

High-income countries generate on average up to 0.5 kg of hazardous waste per hospital bed per day, while low-income countries generate on average 0.2 kg. However, health-care waste is often not separated into hazardous or non-hazardous wastes in low-income countries making the real quantity of hazardous waste much higher (WHO, 2024).

Metrics and numeric limits

Classification of healthcare waste (HCW) that can inform the metrics is shown in the Basel Convention (Basel Convention and WHO, 2005):

Healthcare waste for the purpose of transboundary movements under the Basel Convention can be classified with the codes Y1 (Clinical wastes from medical care in hospitals, medical centres and clinics) or Y2 (Wastes from the production and preparation of pharmaceutical products, or Y3 (Wastes pharmaceuticals, drugs and medicines), among others.

Key relevant UN convention / multilateral treaty

Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1989). At the time of writing, there were 191 parties to the Basel Convention (UN Treaty Collection, 2019).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Health-care waste contains potentially harmful microorganisms that can infect hospital patients, health workers and the public. Other potential hazards may include drug-resistant microorganisms which spread from health facilities into the environment and bioaccumulation of toxins.

Impacts: Adverse health outcomes associated with health care waste and by-products also include:

- sharps-inflicted injuries;
- toxic exposure to pharmaceutical products, in particular, antibiotics and cytotoxic drugs released into the surrounding environment, and to substances such as mercury or dioxins, during the handling or incineration of health-care wastes.
- chemical burns arising in the context of disinfection, sterilization or waste treatment activities;
- air pollution arising as a result of the release of particulate matter during medical waste incineration;
- thermal injuries occurring in conjunction with open burning and the operation of medical waste incinerators;
- radiation burns; and
- spread of antimicrobial resistance through unsafe storage, treatment and disposal of pharmaceutical waste.

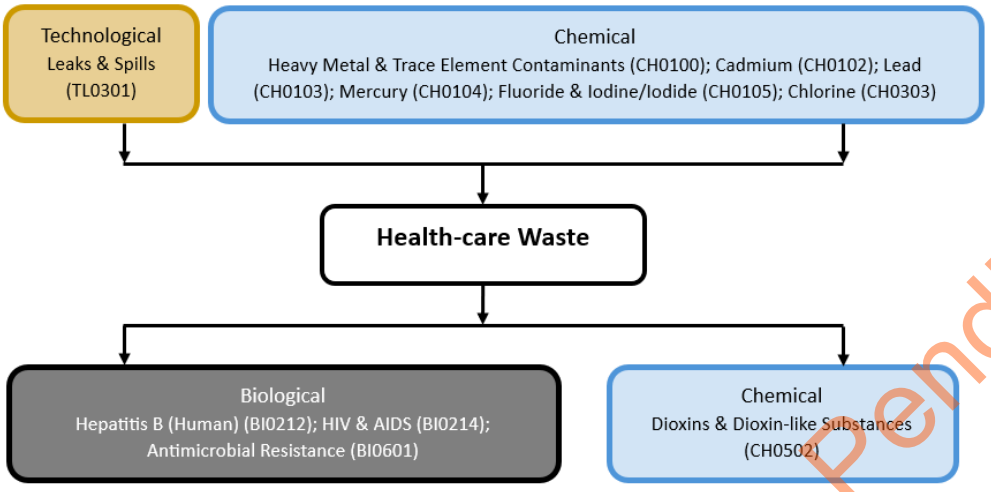
Worldwide, an estimated 16 billion injections are administered every year. Not all needles and syringes are disposed of safely, creating a risk of injury and infection and opportunities for reuse. Injections with contaminated needles and syringes in low- and middle-income countries have reduced substantially in recent years, partly due to efforts to reduce the reuse of injection devices (WHO, 2024). Despite this progress, in 2010, unsafe injections were still responsible for as many as 33,800 new HIV infections, 1.7 million hepatitis B infections and 315,000 hepatitis C infections (Peplin et al, 20141). A person who experiences one needle stick injury from a needle used on an infected source patient has risks of 30%, 1.8%, and 0.3% respectively of becoming infected with HBV, HCV and HIV.

Additional hazards occur from scavenging at waste disposal sites and during the handling and manual sorting of hazardous waste from health-care facilities. These practices are common in many regions of the world, especially in low- and middle-income countries. The waste handlers are at immediate risk of needle-stick injuries and exposure to toxic or infectious materials.

Multi-hazard Context The figure below summarises common interactions between health-care waste and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause,

Preliminary – Corrections Pending

amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring health-care waste. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Regulatory agencies; health and safety agencies; fire services; health services; and manufacturers of chemicals provide material safety data sheets.
How is the Hazard Observed/Monitored/Forecast?	Includes waste site sensors; monitoring and alarm systems; preventative maintenance and inspection, surveillance of health care staff and waste handlers.

Risk Management: According to WHO/UNICEF, in 2021, only 61% of hospitals had basic health-care waste services. The situation is far worse in fragile contexts, where based on 2023 data, only 25% of health facilities had basic health care waste management services (WHO/UNICEF, 2024).

Treatment and disposal of health-care waste may pose health risks indirectly through the release of pathogens and toxic pollutants into the environment (WHO, 2024). Issues identified include:

- The disposal of untreated health-care wastes in landfills can lead to the contamination of drinking, surface, and ground waters if those landfills are not properly constructed.
- Minimization of health-care waste should be a priority. This will significantly reduce the amount of waste that needs to be handled and treated. Waste minimization actions include green procurement and selecting products where shipping is minimized and with less, and ecological, packaging, switching to re-usables when safe and viable, only ordering/receiving pharmaceuticals based on documented need, and recycling common items including plastic, paper and cardboard.
- The treatment of health-care wastes with chemical disinfectants can result in the release of chemical substances into the environment if those substances are not handled, stored and disposed of in an environmentally sound manner.
- Incineration of waste is widely practised, but inadequate incineration or the incineration of unsuitable materials results in the release of pollutants into the air and in the generation of ash residue. Incinerated materials containing or treated with chlorine can generate dioxins and furans, which are human carcinogens and have been associated with a range of adverse health effects. Incineration of heavy metals or materials with high metal content (in particular lead, mercury and cadmium) can lead to the spread of toxic metals in the environment.
- Only modern incinerators operating at 850-1100 °C and fitted with special gas-cleaning equipment are able to comply with the international emission standards for dioxins and furans.
- Alternatives to incineration such as autoclaving, microwaving, and steam treatment integrated with internal mixing, which minimize the formation and release of chemicals or hazardous emissions should be given consideration in settings where there are sufficient resources to operate and maintain such systems and dispose of the treated waste (WHO, 2024).

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Several reasons exist for inadequate health-care waste services. These include limited legal frameworks (e.g. policies, regulation, guidelines), lack of awareness about the health hazards related to health-care waste, inadequate training in proper waste management, absence of waste management and disposal systems, insufficient financial and human resources and low priority. Many countries either do not have appropriate regulations, or do not monitor and enforce them (WHO, 2024).

The management of health-care waste requires increased attention and diligence to avoid adverse health outcomes associated with poor practice, including exposure to infectious agents and toxic substances (WHO, 2024). Safe management of healthcare waste involves three key principles: reduction of unnecessary wastes, separation of general waste from hazardous wastes, and waste treatment that reduces risks to health workers and the community. Safe waste management is a cross-cutting issue and while it is being addressed as part of the global activities on WASH in healthcare facilities, there are a number of ongoing collaborations with teams working on infection prevention and control, injection safety, immunizations, chemicals, energy, and emergencies (WHO, no date).

WHO activities in this area include:

- developing technical guidance materials for assessing the quantities and types of waste produced in different facilities;
- creating national policies and action plans, and developing national health-care waste management guidelines; and
- building capacity at national level to enhance the way health-care waste is dealt with in low-income countries (WHO, no date).

WHO (2024) consider that the key elements in improving health-care waste management are:

- promoting practices that reduce the volume of wastes generated and ensure proper waste segregation;
- developing strategies and systems along with strong oversight and regulation to incrementally improve waste segregation, destruction and disposal practices with the ultimate aim of meeting national and international standards;
- where feasible, favouring the safe and environmentally sound treatment of hazardous health-care wastes (e.g. by autoclaving, microwaving, steam treatment integrated with internal mixing, and chemical treatment) over medical waste incineration;
- building a comprehensive system, addressing responsibilities, resource allocation, handling and disposal. This is a long-term process, sustained by gradual improvements;
- raising awareness of the risks related to health-care waste, and of safe practices; and
- selecting safe and environmentally friendly management options, to protect people from hazards when collecting, handling, storing, transporting, treating or disposing of waste.
- Government commitment and support is needed for universal, long-term improvement, although immediate action can be taken locally.

WHO developed the first global and comprehensive guidance document, Safe management of wastes from health-care activities, now in its second edition and more recently a short guide that summarizes the key elements as well as guidance on selecting technologies (WHO, 2020) The guide addresses the regulatory framework, planning, waste minimization and recycling, handling, storage and transportation, treatment and disposal options, and training. The document is aimed at health-care facility managers, policymakers, public health professionals and waste experts.

In addition, as part of monitoring Sustainable Development Goal 6 on safely managed water and sanitation, the WHO/UNICEF Joint Monitoring Programme regularly publishes data and reports on the safe management of healthcare waste in health-care facilities (WHO/UNICEF, 2024).

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Coordinating agency or organisation

World Health Organization.

Preliminary – Corrections Pending

TL0509 / TECHNOLOGICAL / Waste

Landfilling

Definition

Landfilling is the final placement of waste in or on the land in a controlled or uncontrolled way according to different sanitary, environmental protection and other safety requirements (UN Data, no date).

Reference

UN Data, no date. Environmental Indicators: Waste. United Nations Data. Environment Glossary https://data.un.org/Glossary.aspx?q=landfilling Accessed 21 May 2025.

Annotations

Synonyms

Dumping ground, Waste disposal site, Dumpsite (including engineered dumpsite), Garbage tip, Rubbish pile, Dump waste (including fly-tip).

Additional scientific description

The following distinction between landfill and dumpsite is provided by the Joint United Nations Environment Programme / United Nations Office for the Coordination of Humanitarian Affairs Environment Unit (Joint UNEP/OCHA Environment Unit, 2013):

- *Landfill:* A scientifically designed and constructed site where waste is disposed of systematically, and where all emissions of gases, liquids and solid materials are controlled and not allowed to contaminate the surrounding environment.
- *Dumpsite*: A non-scientifically designed and constructed site where waste is disposed of unsystematically, and where gas emissions, liquid leakage and solids contamination of the surrounding environment are not controlled or managed and where scavenging by waste pickers often takes place.

Other mechanisms for defining landfilling exist. The Basel Convention assists in defining these. Waste deposits into or onto land are used for the disposal of waste in most countries. If these deposits are not designed and operated in an environmentally sound manner, they can present risks to human health and the environment (Basel Convention Secretariat, 2019). Specially engineered landfill (e.g., placement into lined discrete cells which are capped and isolated from one another and the environment, etc.) allows for the final disposal of hazardous wastes and other wastes in an environmentally sound manner with limited impact to water, air, soil, plants or animals, and for control over noise or odours without adverse effects on the landscape, places of special interest and the environment (Basel Convention Secretariat, 2019).

The Basel Convention Technical Guidelines on Specially Engineered Landfill (Basel Convention Secretariat, 2002) also identify the following types of landfill: historic, closed sites; historic, still operating; green field sites; specific operational types of landfill (containment sites and landfills providing for attenuated release); specially engineered landfill.

A report by the International Solid Waste Association noted that as of 2015, dumpsites received about 40% of the world's waste (including municipal solid waste, sewage sludge, hazardous waste, e-waste, healthcare risk waste etc.) (ISWA, 2015). The report went on to suggest that the 50 biggest dumpsites in 2015 were daily affecting the lives of at least 64 million people. A series of studies documented that dumpsites can have serious effects on the health and well-being of the population and environment (ISWA, 2015).

Preliminary – Corrections Pending

Metrics and numeric limits

Not available.

Key relevant UN convention / multilateral treaty

Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1989). At the time of writing, there were 187 parties to the Basel Convention (UN Treaty Collection, 2019).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Landfills are vulnerable to natural hazards, which can exacerbate inherent risks. In particular, if waste is dispersed due to flooding, a larger area can become contaminated. Landfills located in areas prone to slopes or erosion are susceptible to structural defects, which can lead to the dispersion of waste.

Impacts: A wide range of toxic substances for human health can be released into the environment from uncontrolled waste disposal, such as methane, carbon dioxide, benzene, dioxins, carcinogens, persistent organic pollutants, asbestos and cadmium (see relevant chemical HIPs). Hazardous compounds from industrial production such as asbestos and lead are also likely to be found at dumpsites.

The health and environmental impacts of landfills and dumpsites are particularly associated with the emissions from waste decomposition, namely leachate and biogas. Leachate if not properly controlled, may pass through the underlying soil and contaminate sources of drinking water, as well as surface water. The decomposition of waste also brings about the generation of gases, mainly a mixture of methane and carbon dioxide (about 50-50% in anaerobic conditions), known as 'biogas'. Methane is lighter than air and highly flammable. If it enters a closed building and the concentration increases to about 5-15% in the air, a spark or a flame is likely to cause a serious explosion. In addition, if open the burning of solid waste occurs (a normal practice to reduce volume), it could result in the emission of toxic substances tino the air from the burning of plastics and other materials (ISWA, 2015:11).

Landfills and dumpsites can also cause soil pollution. Leachate from the waste matrix carries different metals, which are then transferred to plants in the soil by different pathways and eventually end up either in water held in the soil or leached to the underground water table or aquifers (ISWA, 2015). Waste in open dumps may become a breeding ground for insects, rodents and other disease vectors (WHO, 2013).

Epidemiological studies demonstrate that from the human health perspective, cancer and congenital malformation are potential health outcomes associated with exposure to dumpsites (ISWA, 2015). Collapse of sites has become more frequent at solid waste final disposal sites in urban areas in low- and lower-middle-income countries, causing casualties. Uncontrolled dumpsites are often heavily scavenged by waste pickers exacerbating potential exposure contact. Health risks can be decreased through the implementation of on-site measures (ISWA, 2015).

Multi-hazard Context: The figure below summarises common interactions between landfilling and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

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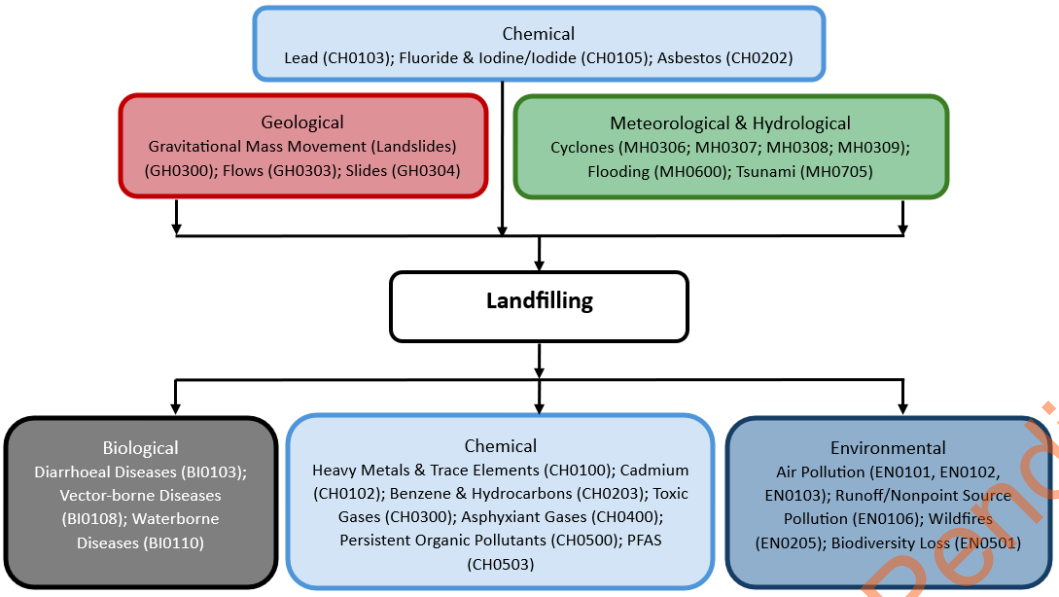

Monitoring: Monitoring plays a crucial role in landfill management, helping to detect and prevent environmental pollution and safety risks early on. For example, isotope-based early warning models are used to detect groundwater (Sappa et al., 2023) and surface water contamination, and gas monitoring wells are installed around landfills to detect methane gas leaks (2A Magazine, 2024). This involves collecting and processing physical and geochemical data.

Risk Management: Guidelines for National Waste Management Strategies: Moving from Challenges to Opportunities – a joint effort of the United Nations Environment Programme and the United Nations Institute for Training and Research – provides a conceptual and methodological framework for national planning that countries may adapt to their particular circumstances. It also establishes a clear rationale for making waste management a national priority (UNEP and UNITAR, 2013).

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Coordinating agency or organisation

Not identified.

Preliminary – Corrections Pending

TL0510 / TECHNOLOGICAL / Waste

Waste Treatment Lagoons

Definition

Waste [treatment] lagoons can be defined as impoundments made by excavation or earth fill for the biological treatment of animal and other agricultural waste (Spellman & Bieber, 2012).

Reference

Spellman, F.R. and R.M. Bieber, 2012. Environmental Health and Science Desk Reference. Government Institutes, 807.

Preliminary – Corrections Pending

Annotations

Synonyms

Not applicable.

Additional scientific description

In recent decades, livestock production (e.g., pig farms, dairies, poultry industry) has increased rapidly. Increased production comes from industrial farms clustered around major urban centres (FAO, 2007). Livestock waste is a major source of greenhouse gases, air pollutants, harmful pathogens and odour (Sorathiya et al., 2014). Concentrations of animals (including intensive farming) and animal wastes close to dense human populations can cause large-scale environmental problems including soil, water, air pollution, and biodiversity loss and may negatively impact human health. It is potentially more dangerous if such concentrated production is conducted in areas near water sources (FAO, 2007).

The term 'lagoon' is often misused, mistakenly including manure storage basins as lagoons (Hamilton et al., 2006). Manure storage basins are not meant to provide significant biological treatment or long storage periods (Livestock and Poultry Environmental Learning Community, 2019).

'Lagoons' can be anaerobic, aerobic, naturally-aerobic, mechanically aerated and facultative, depending on their loading and design (Miller et al., 2011). Lagoons rely on physical, chemical, and biological processes to degrade manure (Hamilton et al., 2006; Miller et al., 2011).

Metrics and numeric limits

Not available.

Key relevant UN convention / multilateral treaty

Not identified.

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Effluents from livestock industrial production are commonly discharged into the environment or stored in 'lagoons', from which waste may spill or leak into nearby streams and groundwater supplies. Noxious gases escape into the atmosphere, subjecting downwind neighbours to noxious odours and contributing to atmospheric aerosol formation, build-up of greenhouse gases and acid rain (FAO, 2007).

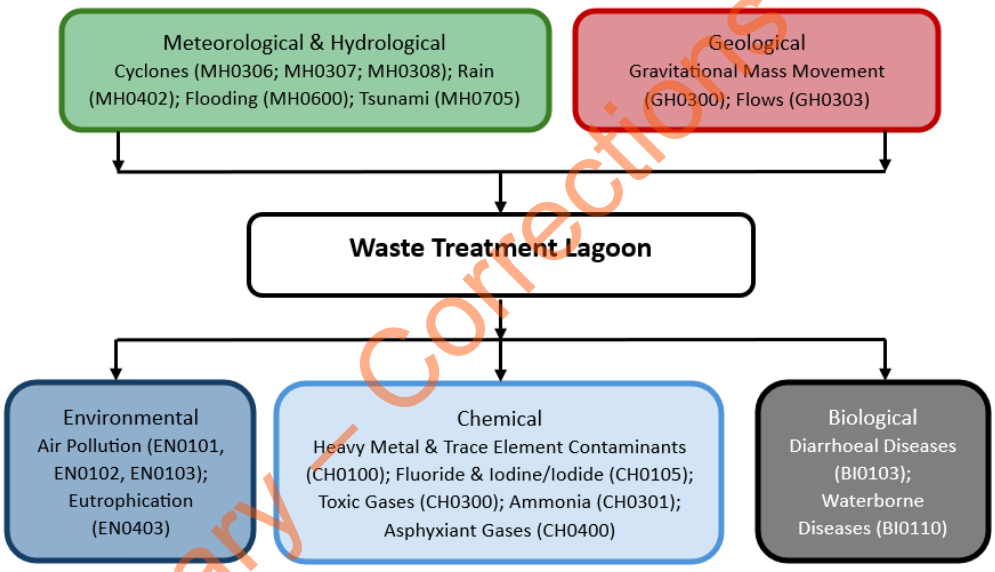
Impacts: The environmental and public health risks of industrial feedlots and effluent lagoons can be limited by ensuring that they are not located too close to each other, to streams and aquifers and to densely populated communities. Environmental damage can be reduced further by encouraging and enforcing standards for the design and construction of buildings and lagoons to conform with approved manure management system (FAO, 2007). Meat processing plants produce large amounts of slaughter- house wastewater, treatment and final disposal (Bustillo-Lecompte & Mehrvar, 2017). Livestock waste lagoons and manure storage basins may spill or leak into nearby streams and groundwater supplies. Furthermore, cracks, improper construction, increased rainfall, storm or stronger-than-normal winds can cause lagoon overflow. Ponds or lagoons used to store

effluents should be lined to reduce leaching and be big enough to allow for manure storage at times when application on crops is not suitable, such as during the rainy season (FAO, 2007). Overflow can spread harmful bacteria, pesticides, animal antibiotics, additional oestrogens, heavy metals, and protozoa into the groundwater supply and contaminate surrounding areas and these could be identified as socio-economically generated sediments (Sharma & Singh, 2015).

Pollution associated with animal waste management in intensive livestock production include (FAO, 2007):

- Leaching of nitrates into groundwater, threatening drinking water supplies.
- Eutrophication of surface water, as nitrogen, phosphorus and other nutrients are discharged or run off into streams, damaging wetlands and fragile coastal ecosystems, and fuelling algae 'blooms' that use up oxygen in the water, killing fish and other aquatic life.
- Build-ups of excess nutrients and heavy metals in the soil, damaging soil fertility and shrinking arable land resources.
- Contamination of soil and water resources with pathogens, heavy metals or drug residues.
- Release of ammonia, hydrogen sulphide, methane, carbon dioxide and other gases into the air, some of which can negatively impact health hazards, damage crops and ecosystems.

Multi-Hazard Context: The figure below summarises common interactions between waste treatment lagoons and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: Not Applicable

Risk Management: Effective policies and legislation to regulate intensive livestock operations and support environmentally and economically sustainable approaches, the use of adequate practices and technologies are of high importance for addressing these challenges and mitigating production of the pollutants. Livestock waste is a major source of nutrients and energy which contributes to improving the circular bioeconomy. Proper management and use of livestock waste as a fertiliser or for conversion into biogas, compost and vermicompost is a useful means to increase crop yield, sustainability, and income (Sorathiya et al., 2014).

Preliminary - Corrections Pending

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Coordinating agency or organisation

Food and Agriculture Organization of the United Nations.

Preliminary – Corrections Pending

TL0511 / TECHNOLOGICAL / Waste

Tailings

Definition

Tailings are a by-product of mining, consisting of the processed rock or soil left over from the separation of the commodities of value from the rock or soil within which they occur (adapted from GISTM, 2020).

Reference

GISTM, 2020-. Global Industry Standard on Tailings Management. https://globaltailingsreview.org/wp-content/uploads/2020/08/global-industry-standard_EN.pdf Accessed 21 May 2025

Preliminary – Corrections Pending

Annotations

Synonyms

Mining waste, Mine waste, Extractive waste.

Additional scientific description

Tailings are the fine-grained waste material remaining after the metals and minerals recoverable from processed soil or rock have been extracted. The material is produced at the 'tail end' of the process with a particle size normally ranging from 10 µm to 1.0 mm (UNECE, 2014:3). Tailings are a common by-product of the process of extracting valuable minerals and metals from mined ore. They usually take the form of a liquid slurry made of fine mineral particles, created as mined ore is crushed, ground and processed. Effective tailings management is integral to the safe and sustainable production of metals and minerals (https://globaltailingsreview.org/about-tailings/).

Tailings are produced from several types of mining operations, including aluminium, coal, oil sands, uranium and precious and base metals (Kossoff et al., 2014). The chemical composition of tailings depends on the mineralogy of the ore body, the degree of grinding, the processing activities used to extract metals, the efficiency of the extraction process and other changes that may occur within tailings storage facilities (TSFs). Major components usually include silica also known as silicon dioxide (SiO_2), iron (Fe), oxygen (O), aluminium (Al), calcium (Ca), potassium (K), magnesium (Mg), manganese (Mn), sodium (Na), phosphorus (P), titanium (Ti) and sulphur (S) (Kossoff et al., 2014). Tailings may also contain toxic elements such as arsenic (As) or chemical reagents such as cyanide (CN^-) which can be toxic in sufficient concentrations (Jewell, 1998).

As an example, uranium tailings are radioactive and can retain the radioactive properties of the ore from which they are derived. In parallel, their radioactivity is very long-lived; they contain a range of potentially toxic heavy metals (see chemical HIPs on heavy metals)and other compounds; they may contain sulphidic minerals with the potential to generate acid mine drainage; and the typical range of particle sizes makes them leachable, erodible or prone to failure if they are poorly managed (IAEA, 2004:6).

Tailings are also of concern due to the risk of tailing dam failures (one of the most common tailings storage methods). Failure of mining dams and the release of potentially toxic material can cause fatalities, affect water sources and sediment quality, fish, terrestrial animal life and plant life, cause sometimes irreversible environmental damage, and negatively impact biodiversity and the reputation of the mining industry. For example, on 25 January 2019, 272 people tragically lost their lives when a tailings dam collapsed at Vale's Córrego do Feijão mine in Brumadinho, Brazil.

Metrics and numeric limits

While the exact numbers of TSFs are uncertain and estimates vary, there are thought to be around 8500 TSFs globally (with around 3,250 of these active). The total global volume is unknown (UNEP, 2017) but of the 1743 sites for which data exist, the combined storage volume in 2020 was 45.5 billion m^3. Estimates for the global production of tailings on an annual basis range from 8.85 - 14.4 billion tonnes per annum (Oberle et al., 2020). In 2019, the International Council on Mining and Metals (ICMM), the United Nations Environment (UN Environment) and the Principles for Responsible Investment (PRI) co-convened a global tailings review to establish an international standard (Global Tailings Review, 2019). The outcome of this work led to the publication in August 2020 of the Global Industry Standard on Tailings Management (ICMM, UNEP & PRI, 2020).

Key relevant UN convention / multilateral treaty

Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (1972), also referred to as the 'London Convention' prevents dumping of waste at sea. At the time of writing, there were 87 parties to the London Convention (IMO, 2019).

UNECE Convention on the Transboundary Effects of Industrial Accidents (1992) at the time of writing had 41 Parties (UN Treaty Collection, 1992a).

Convention on the Protection and Use of Transboundary Watercourses and International Lakes (1992) also referred to as the 'Water Convention', applies as industrial accidents at tailings management facilities may lead to water pollution (UNECE, 2014). Serviced by the United Nations Economic Commission for Europe (UNECE), it started as a regional convention but was opened up to countries outside the UNECE region in 2016. At the time of writing, it had 43 parties (UN Treaty Collection, 1992b).

Directive 2006/21/EC on the management of waste from the extractive industries also referred to as the Extractive Waste Directive (2006) (European Commission, 2019).

Directive 2012/18/EU on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC Text with EEA relevance also referred as the Seveso III Directive includes in its scope operational tailings disposal facilities, including tailing ponds or dams, containing dangerous substances (European Commission, 2019).

Examples of hazard drivers, impacts and risk management

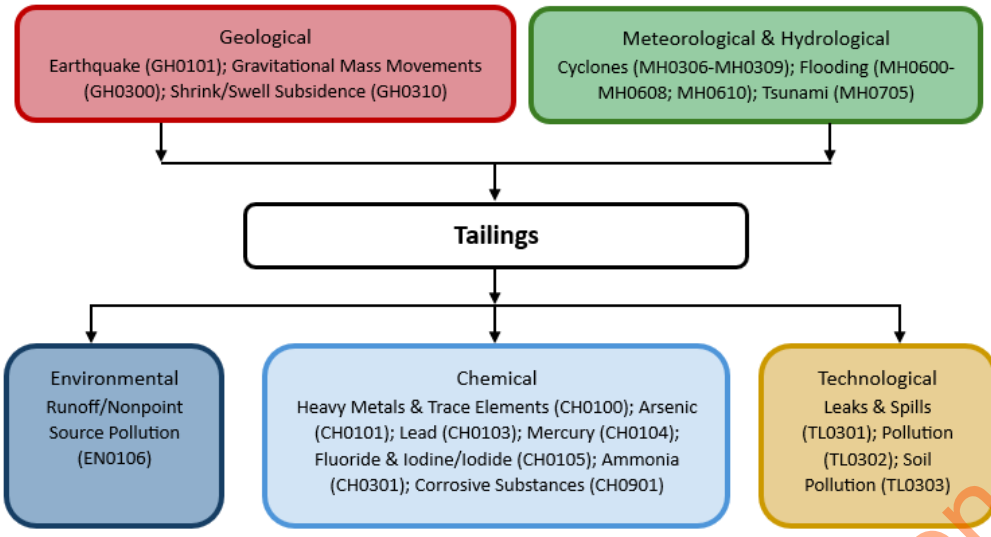
Hazard Drivers: TSF failures are occasionally associated with seismic activity but rarely, as seismicity is typically a critical aspect of the design considerations. One example where this occurred was in 2011 following the 9.0 magnitude earthquake off the coast of Japan's main island, Honshu, that led to the Fukushima Daiichi nuclear disaster.

As extreme rainfall events have become more prevalent due to climate change, this is a complicating factor in the management of water levels within TSFs. Some TSF failures have coincided with periods of heavy rainfall (e.g. the September 2024 failure of a TSF at Lanjigarh in Kalahandi district of Odisha - see here).

Impacts: Tailings may contain heavy metals, arsenic, strong acids and strong bases and release them in the environment.

Multi-hazard Context: The figure below summarises common interactions between tailings and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.

Preliminary – Corrections Pending



Monitoring: The section and the table below offer an overview of monitoring tailings. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	Surveillance programmes implemented by the TSF operator, in some instances in line with regulated requirements
How is the Hazard Observed/Monitored/Forecast?	Instrumentation monitoring - a mix of in-ground (e.g. piezometers, inclinometers) and above-ground (satellite technologies) combined with direct field observations.

Surveillance programmes comprising instrument monitoring and visual inspections are important risk management practices for TSFs, and include internal monitoring (e.g. of deformations, pore pressures, etc.) and external monitoring (e.g. for deformation and leakage). A site-specific operations, maintenance, and surveillance (OMS) manual should be developed that describes OMS requirements based on the TSF consequence classification, current engineering design standards, and site considerations. The OMS manual should include: a description of all monitoring procedures for inspections and instrumentation monitoring; alert and alarm levels for monitored parameters; procedures for reporting on noncompliance, incidents, and failures; corrective actions; emergency plan. (Oberle et al., 2020; World Bank, 2021).

The surveillance programmes should also focus on identifying the conditions that would result in an emergency being declared. Operators should develop and (where necessary) implement a site-specific Emergency Preparedness and Response Plane (EPRP) for such circumstances, in particular for any conditions that could lead to catastrophic failures (ICMM, 2021; ICMM, 2005).

Risk Management: The most commonly used approach to the handling and storage of tailings is within dammed impoundments referred to as 'tailings storage facilities (TSFs)' (Oberle et al, 2020; World Bank, 2021). TSFs are engineered structures that comprise the confining embankments (commonly referred to as tailings dams) and are designed to contain tailings and manage associated water. They contain mixed waste material from mining processes in liquid or slurry form and must be responsibly managed to prevent impacts on human health and safety, the environment, and other infrastructure. Other less commonly used approaches for tailings disposal include riverine disposal, submarine disposal, lacustrine disposal (in lakes), backfilling underground workings, and dry stacking (some of which are dependent on prevailing conditions and regulations and some no longer considered to be good practice).

Tailings are usually stored within TSFs under water to prevent the formation of surface dusts and acid mine drainage (by forestalling oxidation), especially when large amounts of acid-generating pyrite and pyrrhotite are present (Kossoff et al., 2014; Koomsona et al., 2021). This requires careful management of water levels within storage facilities to prevent erosion and related problems.

TSFs require particularly careful management for preventing and minimising air, water, and soil contamination. The rate of failure has been estimated as one in 700 to one in 1750 which is significantly higher than for water-retaining dams - one in 10,000 (David, 2003). Causes of failure include overtopping, poor maintenance, breach following heavy

Preliminary – Corrections Pending

rain, breach following earthquake, foundation failure, and retention wall failure (Kossoff et al., 2014). Furthermore, abandoned mining sites and mining waste storage facilities may contain chemicals and other elements which may be dangerous to human and animal health and to the wider environment.

Effective legal and institutional frameworks for dam safety and environmental protection, implementation and enforcement of relevant laws and safety standards, adequate tailing dam designs based on accurate risk assessments, regular inspections and special monitoring systems are of critical importance for sound tailings management (Centre for Economic Development, Transport and the Environment, 2012).

Application of technology-driven solutions such as remote sensing methods has shown significant development for tailing dam monitoring and early warning systems to prevent their failure. More attention needs to be given to the monitoring of leachate coming out of the ponds/dams.

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Preliminary – Corrections Pending

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Coordinating agency or organisation

Not identified.

Preliminary – Corrections Pending

TL0601 / TECHNOLOGICAL / Radiation

Radioactive Waste

Definition

Radioactive waste is radioactive material for which no further use is foreseen but still contains, or is contaminated with, radionuclides. Radioactive waste can be in gas, liquid or solid form (IAEA, 2018). It may remain radioactive from a few hours to hundreds of thousands of years.

For legal and regulatory purposes, material for which no further use is foreseen that contains, or is contaminated with, radionuclides at activity concentrations greater than clearance levels as established by the regulatory body (Adapted from IAEA, 2018 and IAEA 2022 a).

References

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Annotations

Synonyms

Nuclear waste.

Additional scientific description

It is common regulatory practice to define terms such as radioactive material and radioactive waste to include only material or waste that is subject to regulation by virtue of the radiological hazard that it poses. Although the exact specifications vary from State to State, this typically excludes material and waste with very low concentrations of radionuclides and those that contain only 'natural' concentrations of naturally occurring radionuclides (IAEA, 2018).

Metrics and numeric limits

The International Atomic Energy Agency (IAEA) Glossary of 2018 for radioactive waste classification uses waste classes recommended in IAEA Safety Standards Series No. GSG-1 (IAEA, 2009): High-Level Waste (HLW), Intermediate-Level Waste (ILW), Long-Lived Waste, Low-Level Waste (LLW), Short-Lived Waste, Very Low-Level Waste (VLLW) and Very Short-Lived Waste (VSLW). For a detailed description of each, see IAEA (2009).

Other systems classify waste on other bases, such as according to its origin (e.g., reactor operations waste, reprocessing waste, decommissioning waste and defence waste) (IAEA, 2009).

Preliminary – Corrections Pending

Key relevant UN convention / multilateral treaty

The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (1972), also referred to as the 'London Convention' prevents dumping of waste (including radioactive waste) at sea. At the time of writing, there were 87 parties to the London Convention (IMO, 2019).

The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (United Nations, 1997) entered into force in 2001 and addressed the issue of spent fuel and radioactive waste on a global scale. At the time of writing, there were 71 parties to the convention.

Examples of hazard drivers, impacts, and risk management

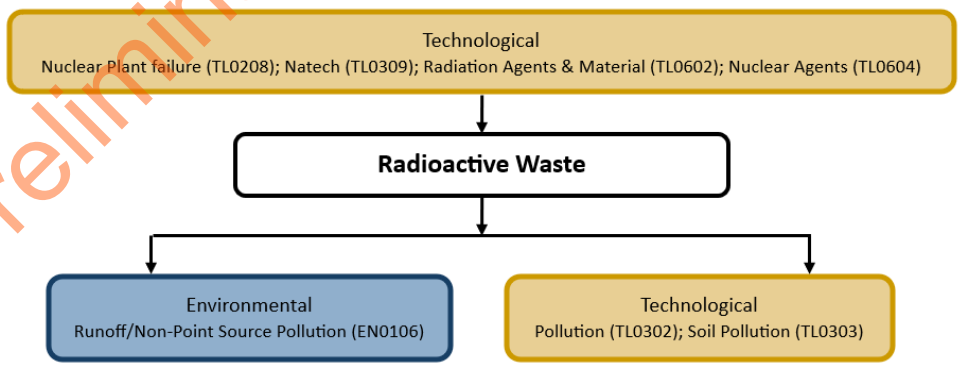
Hazard Drivers: Sources of radioactive waste include medical waste, industrial waste, and tailings from naturally occurring radioactive materials in metallic ores, coal, oil, and gas (Rosenfeld & Feng, 2011), as well as decommissioning of nuclear installations and other nuclear facilities, research reactors, research facilities, and from the production and use of radioisotopes (IAEA, 2009). Nuclear wastes are by-products of nuclear weapons production and nuclear power generation, plus residuals of radioactive materials used by industry, medicine, agriculture, and academia (Gee et al., 2005).

Natural hazards such as earthquakes, floods, fires, and tsunamis can pose significant risks to radioactive waste storage facilities. The Fukushima nuclear power plant accident is a notable example demonstrating the impact of earthquakes and tsunamis on nuclear facilities. Radioactive waste storage sites are vulnerable to a chain of hazards, including structural damage caused by earthquakes, fires, cooling system failures, and more (NCBI, 2021).

Impacts: Radioactive waste containing radioactive material remains hazardous to human, animal and plant health and the environment. External hazards (e.g., causing body damage from overexposure to gamma rays) and/or internal hazards (e.g., causing body damage from alpha and beta particles by contaminated food or air) can be present whenever radioactive materials are found.

In general, exposure to large amounts of radioactivity (from radioactive waste or not) can cause nausea, vomiting, hair loss, diarrhoea, haemorrhage, destruction of the intestinal lining, central nervous system damage, and death. It may also cause DNA damage and increase the risk of cancer, particularly in young children and foetuses. Beyond certain thresholds, radioactivity can impair the functioning of tissues and/or organs and can produce acute effects such as skin redness, hair loss, radiation burns, and/or acute radiation syndrome. These effects are more severe at higher doses and higher dose rates. For instance, the dose threshold for acute radiation syndrome is about 1 Sv (1000 mSv) (IAEA, 1997).

Multi-hazard Context: The figure below summarises common interactions between radioactive waste and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: Not applicable

Risk Management: Currently, no method is known to neutralise radioactive waste (Rosenfeld & Feng, 2011) but long-term isolation in a geoenvironment is recommended. Most nuclear waste is radioactive for a few tens of years and is routinely disposed of in near-surface disposal facilities. About 3% of the total volume of radioactive waste is long-lived and highly radioactive requiring isolation from the environment for multiple millennia (World Nuclear Association, 2017).

Preliminary – Corrections Pending

Communication and stakeholder involvement are essential components for a successful disposal programme. Experience around the world suggests that the scientific and technological bases for the safe disposal of radioactive waste are available – disposal solutions exist or can be developed based on established knowledge. However, concerns and opposition among the public and other stakeholders could slow or even prevent the implementation of needed disposal solutions. IAEA have published practical guidance on communication and stakeholder involvement for countries embarking on, relaunching or revising a disposal programme. It draws upon past experiences and emphasizes that practical implementation requires adjusting to the evolving context as given by the national, social and political circumstances. The primary intended users of this publication include those working in the field of radioactive waste management in government, regulatory bodies and industry, and especially in organisations responsible for implementing solutions for radioactive waste disposal (IAEA, 2022 b).

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Coordinating agency or organisation

Not identified.

Preliminary – Corrections Pending

TL0602 / TECHNOLOGICAL / Radiation

Radioactive Agents & Material

Definition

A substance or a material emitting, or related to the emission of, ionizing radiation (either in the form of electromagnetic waves or particle radiation) is radioactive. Depending on the magnitude of exposure, the radioactive substance may affect human health; as such it is subject to regulatory control by national laws and national regulatory authorities. Radioactive material may also be a hazard to animal health, other forms of life and the environment (IAEA, 2018).

Reference

IAEA, 2018. IAEA Safety Glossary: Terminology used in nuclear safety and radiation protection, 2018 edition. International Atomic Energy Agency (IAEA). www-pub.iaea.org/MTCD/Publications/PDF/PUB1830_web.pdf Accessed 25 January 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Radioactive substance, Radioactive source, Radionuclide.

Additional scientific description

The scientific meaning of radioactive is exhibiting radioactivity, emitting or relating to the emission of ionizing radiation or particles (IAEA, 2022). Depending on the magnitude of exposure, the radioactive substance may become a hazard to human health; as such it is subject to regulatory control by national laws and national regulatory authorities. Radioactive material may also be a hazard to animal health, other forms of life and the environment (IAEA, 2018).

Radioactive materials (natural and human-made) are widely used in industry, medicine and research but can also be used maliciously.

- *Alpha-radiation*: consists of heavy, positively charged particles emitted by atoms of elements such as uranium and radium. Alpha radiation cannot penetrate skin and can be stopped by a thin paper sheet. However, alpha-emitting radioactive material entering the body by breathing, eating, or drinking, can affect organs and tissues and cause biological damage (IAEA, no date a).
- *Beta-radiation*: consists of electrons, is more penetrating than alpha-radiation and can pass through the skin surface. In general, a sheet of aluminium a few millimetres thick will stop beta-radiation (IAEA, no date a).
- *X-rays or Gamma-rays*: electromagnetic radiation similar to light, and radio waves. Depending on their energy, x- or gamma-rays can pass right through the human body, but not through a concrete wall or lead (IAEA, no date a).
- Neutrons: uncharged particles that do not produce ionisation directly but give rise to radiation due to their interaction with the material they traverse. Neutrons are highly penetrating and can only be stopped by thick masses of materials such as concrete, water or paraffin.

Metrics and numeric limits

The magnitude of a source of alpha- or beta-radiation is given by its activity, measured in Becquerel (Bq). 1 Bq corresponds to 1 radioactive decay/second. Sometimes the Curie (Ci), an older, non-SI unit based on the activity of a gram

of radium-226, is still used. 1 Ci is equivalent to 37 GBq. The absorbed dose of any type of radiation is measured in Gray (Gy), and 1 Gy is equivalent to 1 joule of energy absorbed in 1 kg of matter. The impact of radiation on health is measured by the unit 'Sievert' symbolised as Sv.

Dose limits in most countries are set according to the International System of Radiological Protection (ICRP 103; 118), which is based on the principles of justification, optimisation, and dose limitation. Recommendations based on the literature, produced by the International Commission for Radiological Protection, are translated into safety standards by the International Atomic Energy Agency. These are then adopted, or amended and adopted, as legislation at the national or regional levels.

The severity of a radiation emergency is identified by the International Nuclear and Radiological Event Scale (INES) as demonstrated in the graphic below (IAEA, no date). INES is a standard tool for communicating the magnitude of nuclear and radiological events in a consistent manner (IAEA, no date).

Key relevant UN convention / multilateral treaty

Multiple conventions, treaties and agreements, that have been adopted by States, form part of the international nuclear legal framework. Those relevant to emergency situations include the:

Convention on Early Notification of a Nuclear Accident (United Nations Treaty Collection, 1986) and the

Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (United Nations Treaty Collection, 1987).

The main international legal instruments adopted under the IAEA's auspices are the Convention on the Physical Protection of Nuclear Material (CPPNM) and its 2005 Amendment. The CPPNM entered into force on 8 February 1987. It establishes physical protection measures that have to be applied to nuclear material in international transport, as well as measures related to criminal offences related to nuclear material. The Convention also envisages forms of international cooperation among the Parties. On 8 July 2005, the Parties to the Convention adopted by consensus an Amendment to the CPPNM, which entered into force on 8 May 2016. The Convention and the Amendment are the only legally binding international instruments in the area of physical protection of nuclear material. The Amendment constitutes an important milestone in international efforts to improve the physical protection of nuclear material and facilities. Whereas the obligations for physical protection under the CPPNM covered nuclear material during international transport, the Amendment to the CPPNM makes it legally binding for States Parties to protect nuclear facilities and material in peaceful domestic use, storage and transport. It also provides for expanded cooperation between and among States regarding rapid measures to locate and recover stolen or smuggled nuclear material, mitigate any radiological consequences of sabotage, and prevent and combat related offences (IAEA, No date).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: There are a number of types of incidents which may involve radiation agents or materials, i.e. an ionising radiation hazard, in addition to another hazard. For example, natural hazards and disasters, such as earthquakes, floods or wildfires may seriously challenge nuclear installation safety, and some nuclear installations make use of chemicals that would be very damaging to human health and the environment if released in an uncontrolled manner. Tools such as the IAEA External Events Notification System (EENS, see below), help national and international responders to manage such large-scale events. The Fukushima nuclear accident serves as a representative example of the impact these events can have on nuclear facilities (NCBI, 2014).

Radiological hazards can occur through accidental spills of radioactive chemicals in laboratories, reprocessing plants or hospitals (such as a spill of uranyl nitrate) or accidents during radiation therapy. Accidents in nuclear power plants can lead to contamination of territories over thousands of square kilometres over tens to hundreds of years by alpha-, beta- and gamma radiation, requiring zoning and evacuation measures (IAEA, no date).

Exposure to radiation may be external, internal, or combined, and can occur through various exposure pathways (Nuclear emergencies: information for the public - GOV.UK (www.gov.uk)). Exposure to radiation can be classified into three exposure situations: planned exposures (occupational and medical exposures); existing exposures (natural sources such as radon gas or residual radiation from past accidents or industrial activities); and emergency exposures (radiological and nuclear emergencies, accidents in transport, medicine, research, or even malicious acts involving radioactive material) (IAEA, 2021).

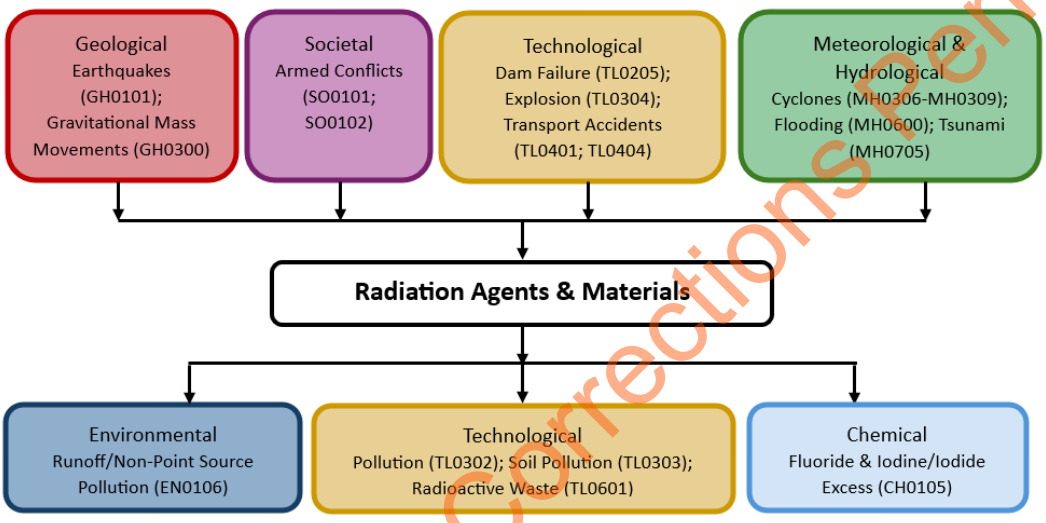
External exposure may occur near an unshielded radioactive source or when airborne radioactive material (such as dust, liquid, or aerosols) is deposited on skin or clothes. This type of radioactive material can often be removed from the body by simply washing (IAEA, 2021). Internal exposure to ionising radiation occurs when a radionuclide is inhaled, ingested or otherwise enters into the bloodstream (e.g., by injection or through wounds). Internal contamination with most radionuclides needs medical intervention to remove radionuclides from the body (IAEA, 2021).

Preliminary – Corrections Pending

Impacts: Studies following survivors of atomic bomb events and radiation industry workers have confirmed that radiation exposure increases the risk of cancer, and the risk increases as the dose increases (UNSCEAR, 2021).

Types of emergencies involving radioactive material range from a small-scale radiological incident involving a lost or stolen industrial radioactive source, over-exposure of a person in an occupational or medical setting, or as a result of a transportation incident; to a large-scale nuclear emergency at a nuclear installation such as a nuclear power plant or a research reactor, or a detonation of a military or improvised nuclear device (IAEA, 2021). Examples of nuclear emergencies are nuclear bomb detonations in Japan at the end of the Second World War; the Three Mile Island and Chernobyl nuclear power plant accidents; and the Great Eastern Japan Earthquake which generated a tsunami and resulted in the Fukushima Daiichi nuclear power plant accident.

Multi-hazard Context: The figure below summarises common interactions between radioactive agents and material and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring radioactive agents & material. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Which institution(s) produce(s) Disaster Risk Data/Information?	IAEA
How is the Hazard Observed/Monitored/Forecast?	The IAEA International Radiation Monitoring Information System is a web-based tool for sharing, aggregating and visualizing large quantities of radiation monitoring data during a nuclear or radiological incident or emergency, to aid in decision-making. IRMIS has been developed to support the implementation of the Early Notification Convention, facilitating the reporting and visualization of large quantities of radiation monitoring data during nuclear or radiological incidents or emergencies. In addition, IRMIS supports and enhances some of the features of the Unified System for Information Exchange in Incidents and Emergencies (USIE) (IAEA, 2020). In addition, the IAEA External Events Notification System (EENS) is a web-based tool which provides real time information on external events and hazards, such as earthquakes, tsunamis, volcano eruptions, river and coastal flooding, rotational winds and wildfires, that have occurred or are expected to occur, including on their severity and location, as well as estimations of their potential effects on nuclear installations and major population centres. The system collects relevant data and sends it directly to the IAEA's Incident and Emergency Centre (IEC) and External Event Safety Section (EESS) for assessment.

Risk Management: Protective actions to prevent or reduce radiation exposure in the case of a radiation emergency situation depend on the type of emergency and may include: taking shelter; evacuation or even permanent relocation from an affected area; restriction of the consumption of contaminated food or water; administration of iodine thyroid blocking (in the case of radioactive iodine release, see the HIP on Iodine/Iodide excess/inadequate intake CH0105); monitoring and measuring radiation in affected people and the environment; securing radioactive sources and cleaning up affected areas;

Preliminary – Corrections Pending

as well as providing information, risk communication, psychological support, medical care and long-term follow-up to those in need (IAEA, 2021).

Other risk management measures include (IAEA, 2021):

- Safe siting, design and construction of nuclear power plants as well as controls and backup measures for their safe operation and radioactive waste management and isolation from the geo-environment.
- Controls, equipment and training to protect personnel working with radioactive sources.
- Security measures to control access to supply and use of radiation sources.
- Facility, local and national multisectoral radiation emergency response plans for a range of scenarios from low-level exposure to a significant release of radioactivity.
- Effective risk communication is essential to the public and emergency responders (WHO, 2022).
- Consideration of the psychosocial impact of radiation incidents, including on mental health.

The Code of Conduct on the Safety and Security of Radioactive Sources (the Code) was established to achieve and maintain a high level of safety and security of radioactive sources across the globe. Following the terrorist attacks on 11 September 2001 in the USA, the provisions in the text addressing the security of radioactive sources were enhanced. In September 2003, the Code was approved, and the International Atomic Energy Agency (IAEA) General Conference invited States to make a political commitment to work towards the principles therein and currently 119 States have done so (IAEA, no date b).

The IAEA Preventive Measures for Nuclear and Other Radioactive Material out of Regulatory Control elaborates upon the recommendations given in IAEA Nuclear Security Series No. 15, Nuclear Security Recommendations on Nuclear and Other Radioactive Material out of Regulatory Control, in relation to preventative measures (IAEA, 2019). It serves as a guidance document for Member States interested in strengthening their nuclear security regime as it relates to nuclear and other radioactive material out of regulatory control and in improving their capabilities.

There are also a number of different monitoring and early warning systems for hazards that can result in the release of radioactive agents or materials at local, national and international levels. Early Warnings for All was launched in 2022 by the UN, with the aim to protect everyone on Earth from hazardous weather, water, or climate events through life-saving early warning systems by the end of 2027 (Early Warnings for All, 2022).

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Coordinating agency or organisation

Not identified.

Preliminary – Corrections Pending

TL0603 / TECHNOLOGICAL / CBRNE (Chemical, Biological, Radiological, Nuclear and Explosive)

Nuclear Agents

Definition

Nuclear agents are derived from neutron radiation (n) which is a neutron emitted by an unstable nucleus, in particular during atomic fission and nuclear fusion. Apart from a component in cosmic rays, neutrons are usually produced artificially. Because they are electrically neutral particles, neutrons can be very penetrating and when they interact with matter or tissue, they cause the emission of beta- and gamma-radiation. Neutron radiation therefore requires heavy shielding to reduce exposure (IAEA, 2004).

Reference

IAEA, 2004. Radiation, People and the Environment. International Atomic Energy Agency (IAEA). www.iaea.org/sites/default/files/radiation0204.pdf Accessed 1 December 2019.

Preliminary – Corrections Pending

Annotations

Synonyms

Not available.

Additional scientific description

Dispersal of neutron radiation through nuclear weapons, including improvised nuclear devices (IND) results in a nuclear yield unlike radiation dispersal devices (RDD). This nuclear yield is measured in kilotons (kT) and one unit has the explosive energy equivalent to a thousand tons of TNT. Nuclear detonations are capable of producing impacts far surpassing that of any conventional explosive (IAEA, 2004).

A significant effect of a nuclear explosion is the blast generated. The blast originates from the rapidly expanding fireball of the explosion, which generates a pressure wave moving rapidly away from the point of detonation. Initially, near the point of detonation (also referred to as 'ground zero') for a surface nuclear burst, the overpressure is extremely high. With increasing distance from ground zero, the overpressure and speed of the blast wave dissipate to a point at which they cease to be destructive. In the case of a nuclear terrorism incident, the thermal pulse can cause skin burns on those people within a few miles of the incident who have a line-of-sight view of the fireball (IAEA, 2004).

There will be many hazards after a nuclear terrorism incident, including widespread fires and the presence of toxic materials, but one of the most significant in terms of human health for a ground-level or near-ground-level nuclear incident, will be the residual radiation from radioactive fallout and neutron activation of materials. Although the radiation levels are most hazardous in the first few hours, some areas within a few miles downwind may still be hazardous days after the incident. Rapid identification of these fallout areas for implementation of protective measures is one of the highest priorities for emergency management and public health authorities (IAEA, 2004).

Metrics and numeric limits

Identifying the dangerous-radiation zone (exposure rate ≥10 R h^{-1}, ₃0.1 Gy h^{-1} air-kerma rate) will have critical

implications on response activities in or near fallout areas. The dangerous-radiation zone is an area where large doses could be delivered to emergency responders in a short period of time. The relation of dose and health effect is mainly established via the survivors of the bombs of Hiroshima and Nagasaki, assessed in 1950 and continued by the US Atomic Bomb Causality Commission (ABCC) and its successor, the USA-Japan binational Radiation Effects Research Foundation (RERF) (NCRP, 2010).

After a ground-level nuclear terrorism incident, the dangerous-radiation zone will be created by fallout that is deposited in the first few hours and will have boundaries that may extend for 20 miles (~32 km), depending on the yield and weather. The dangerous-radiation zone will rapidly shrink as the fallout decays and may only be a mile or two long after a few days. As an example, an emergency responder working in an area with an initial 10 R h^{-1} exposure rate (~0.1 Gy h^{-1} air-kerma rate) 4 hours after the nuclear terrorism incident will receive ~25 R (~0.25 Gy air kerma) in a 4-hour work period (NCRP, 2010).

Key relevant UN convention / multilateral treaty

Effective national and global response arrangements and capabilities are essential to minimise the impacts of nuclear and radiological incidents and emergencies. The International Atomic Energy Agency (IAEA) maintains the international Emergency Preparedness and Response (EPR) framework, which is based on international legal instruments (IAEA, 2019).

As part of these activities, the IAEA develops safety standards, guidelines and technical tools; assists Member States in building the capacity for emergency response; and maintains the IAEA Incident and Emergency System to efficiently implement its role in response to nuclear or radiological incidents and emergencies, regardless of whether they arise from accident, negligence or deliberate act.

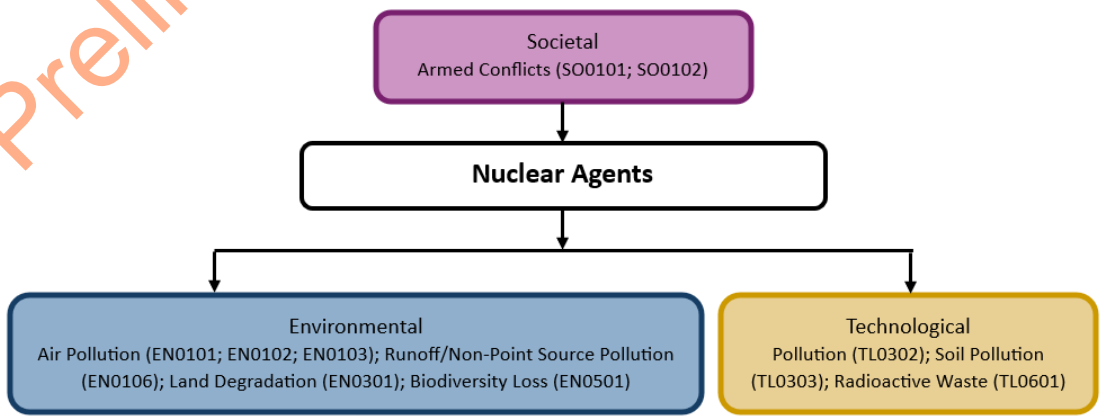
The IAEA Preventive Measures for Nuclear and Other Radioactive Material out of Regulatory Control elaborates upon the recommendations given in IAEA Nuclear Security Series No. 15, Nuclear Security Recommendations on Nuclear and Other Radioactive Material out of Regulatory Control, in relation to preventative measures (IAEA, 2019). It serves as a guidance document for Member States interested in strengthening their nuclear security regime as it relates to nuclear and other radioactive material out of regulatory control and in improving their capabilities.

Examples of hazard drivers, impacts, and risk management

Hazard drivers: Nuclear agents, resulting in the dispersal of neutron radiation are associated with nuclear weapons, including improvised nuclear devices (IND). Conflicts and accidents at production or storage sites may also release nuclear agents.

Impacts: A life-span study to investigate the health consequences on a large population after the bombs of Hiroshima and Nagasaki, showed that the survivors within 1500 m of the epicentre (shielded whole body kerma >1 Gy) on average had a reduction of 2.6 years of life expectancy due to radiation-induced cancer (Smith, 2007).

Multi-hazard Context: The figure below summarises common interactions between nuclear agents and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: The section and the table below offer an overview of monitoring nuclear agents. This information can be used for forecasting within a national early warning system (EWS). Since EWS capacities and processes differ across countries, the most current and specific information regarding EWS should be obtained from the appropriate national or regional agency/authority responsible for disaster management.

Preliminary – Corrections Pending

Which institution(s) produce(s) Disaster Risk Data/Information?	Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO); International Atomic Energy Agency (IAEA)
How is the Hazard Observed/Monitored/Forecast?	CTBTO operates International Monitoring System (IMS) that consists of 321 monitoring stations hosted by 89 countries. This IMS includes verification methods using seismic stations to monitor underground tests by measuring shockwaves, hydroacoustic stations to detect soundwaves, infrasound stations, and radionuclide stations to detect radioactive particles or gases (CTBTO, No date). IAEA organises visits to nuclear sites

Risk Management: Protective actions to prevent or reduce radiation exposure in the case of a radiation emergency situation depend on the type of emergency and may include: taking shelter; evacuation or even permanent relocation from an affected area; restriction of the consumption of contaminated food or water; administration of iodine thyroid blocking (in the case of radioactive iodine release, see the HIP on Iodine/Iodide excess/inadequate intake CH0105)); monitoring and measuring radiation in affected people and the environment; securing radioactive sources and cleaning up affected areas; as well as providing information, risk communication, psychological support, medical care and long-term follow-up to those in need (IAEA, 2021).

An Early Warning System (EWS) related to nuclear agents provides early alerts for events such as the release of nuclear materials, radiation leaks, and nuclear accidents, aiming for immediate response and prevention. This system primarily utilizes radiation detection equipment, satellite data, ground sensors, and automated alert mechanisms to detect signs of nuclear incidents in real time and send warnings. The EWS quickly detects the release of nuclear materials and sends alerts to regions that may face severe radiation exposure or areas where the materials could spread in the atmosphere, allowing people to take appropriate evacuation or radiation protection measures.

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Coordinating agency or organisation

Not identified.

Preliminary – Corrections Pending

SOCIETAL

Preliminary – Corrections Pending

SO0101 / SOCIETAL / Conflict

International Armed Conflict (IAC)

Definition

International armed conflict covers all cases of declared war and other de facto armed conflict between two or more States, even if the state of war is not recognised by one of them and/or the use of armed force is unilateral (ICRC, 2024).

Reference

ICRC, 2024, Opinion Paper, "How is the term 'armed conflict' defined in IHL?" https://www.icrc.org/sites/default/files/document_new/file_list/armed_conflict_defined_in_ihl.pdf. Accessed 31 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Interstate armed conflict, State-based armed conflict. IAC.

Additional scientific description

Common Article 2 of the Geneva Conventions of 1949 defined International Armed Conflict (IAC) as, "all cases of declared war or of any other armed conflict which may arise between two or more of the High Contracting Parties, even if the state of war is not recognized by one of them." IAC "exists whenever there is a resort to armed force between States" (ICTY, 1995) and "can always be assumed when parts of the armed forces of two States clash with each other" (Schindler, 1979). The Geneva Conventions refer to States that are party to the Conventions as 'High Contracting Parties'.

International armed conflict is conceptually broader and more flexible than the notion of war between States because IAC is based on objective and factual criteria and does not rely on the formal declaration of war (ICRC, 2016). By extension, the termination of IAC is based on evidence on the ground and not a ceasefire or peace agreement (ICRC, 2016). Article 6(2) of the Fourth Convention stipulates that the Convention ceases to apply when there is objective evidence of "the general close of military operations" and the International Criminal Tribunal for the former Yugoslavia (ICTY) ruled that International Humanitarian Law "extends beyond the cessation of hostilities until a general conclusion of peace is reached" (ICTY, 1995: para. 70).

The category of IAC encompasses a broad range of armed confrontations between two or more States including, but not limited to:

- "All cases of partial or total occupation of the territory of a High Contracting Party, even if the said occupation meets with no armed resistance" (ICRC, 1949, Article 2[2]).
- "An unconsented-to invasion or deployment of a State's armed forces on the territory of another State – even if it does not meet with armed resistance" (ICRC, 2016, para. 223).
- The use of armed force not directed against the enemy's armed forces but only against the enemy's territory, its civilian population and/or civilian objects, including (but not limited to) infrastructure (ICRC, 2016, para. 224)
- "Armed conflicts in which peoples are fighting against colonial domination, alien occupation or racist regimes" (ICRC, 1977, Additional Protocol I, Article 1[4], para. 1).
- "Minor skirmishes between the armed forces, be they land, air or naval forces" Any unconsented-to military operations by one State in the territory of another State (ICRC, 2016, para. 237).
- When a situation objectively shows for example that a State is effectively involved in military operations or any other hostile actions against another State, neutralizing enemy military personnel or assets, hampering its military operations or using/controlling its territory (ICRC, 2016 para. 241)
- Cyber operations having similar effects to classic kinetic operations (ICRC, 2016, para. 255)
- State's overall control over non-State armed groups fighting another State (ICRC, 2016, para. 265 and sq.)

Metrics and numeric limits

The identification and classification of IAC is not conducted by a central authority, and there is no minimum threshold of intensity or duration for a confrontation to be considered a situation of IAC (ICRC, 2016).

Academic conflict datasets are available; they provide their own operational thresholds for the minimum number of annual fatalities for NIAC events and trends to be included. For example, two of the most influential academic conflict datasets, the Uppsala Conflict Data Program (Uppsala Universitet, no date) and the Correlates of War (The Correlates of War Project, no date) apply annual conflict-related fatality thresholds of 25 and 1000, respectively. The Correlates of War seeks to facilitate the collection, dissemination, and use of accurate and reliable quantitative data in international relations. Key principles of the project include a commitment to standard scientific principles of replication, data reliability, documentation, review, and the transparency of data collection procedures.

Key relevant UN convention / multilateral treaty

Article 2 Common to the Geneva Conventions. Geneva Convention Relative to the Protection of Civilian Persons in Time of War (Fourth Geneva Convention) (ICRC, 1949).

Protocol additional to the Geneva Conventions of 12 August 1949 and relating to the Protection of Victims of International Armed Conflicts (Protocol I) (ICRC, 1977).

Examples of drivers, impacts, and risk management

Hazard Drivers: The Global Platform underscored the security implications of climate change and disasters and encouraged more context-specific disaster risk reduction and resilience-building strategies in conflict-affected countries and fragile contexts based on risk assessments that integrate disaster, climate risks and conflicts (UNDRR, 2019).

Impacts: Armed conflict carries immediate and severe impacts on human lives, health, and dignity with increasing numbers of military personnel and civilians being killed, wounded, treated without dignity, arbitrarily detained and/or separated from their families. They may have been targeted on purpose, forced to leave their homes, and deprived of their basic rights as human beings, such as the right to supplies essential to their survival" (ICRC, 2023).

Impacts could include impacts from the use of biological agents (BI0602), chemical agents (CH0903), nuclear agents (TL0603) and explosive agents (TL0306). Additionally, explosive ordnance (explosives remnants of war) (SO0201) and environmental degradation from conflict (SO0202) may have impacts.

Multi-hazard Context: Since the 1970s, an emerging body of work has sought to deepen and nuance understanding of the construction of disaster risk, and the intersection of natural hazards with violence, conflict and fragility. The interplay between disasters, climate change, environmental degradation, and fragility should be recognized, including in the context of water-related risk (Peters, 2019).

The dynamic nature of systemic risks, new structures to govern risk in complex, adaptive systems and develop new tools for risk-informed decision-making that allow human societies to live in and with uncertainty. This is particularly needed where environmental, health and financial systems, supply chains, information and communication systems are clearly vulnerable. These are challenged by, and are causal drivers of, disruptive influences such as climate change, loss of biodiversity and ecological systems degradation, disease outbreaks, food shortages, social unrest, political instability and conflict, financial instability and inequality. They also create vulnerability on multiple spatial scales (local to global) and across different timescales (from immediate to decadal and beyond) (UNDRR, 2019).

Disasters can also impact people who have already been forcibly displaced by conflict or other reasons (UNDRR, 2025).

Monitoring: Monitoring armed conflicts involves observing, tracking, and analyzing various aspects of conflict situations to understand their dynamics, impact, and potential for escalation or de-escalation. This can be done through various methods, including satellite imagery, field reports, and online portals, with the goal of informing decision-makers and promoting peace efforts.

Various mechanisms exist including the Geneva Academy Rule of Law in Armed Conflict Online Portal (RULAC) which classifies all situations of armed violence that amount to an armed conflict under international humanitarian law. Currently, it monitors more than 110 armed conflicts and provides information about parties, the latest developments, and applicable international law. Some of these conflicts make the headlines, others do not. Some of them started recently, while others have lasted for more than 50 years (Geneva Academy, no date).

Risk Management: Everyone has the right to protection against hazards, regardless of whether they live in a relatively peaceful and stable society, or one where challenges associated with violence, conflict and fragility are rife. Where these challenges exist, vulnerabilities are highest and capacities to manage disaster risk are often insufficient. For these reasons, conflict contexts require dedicated support for disaster risk reduction (Peters, 2019).

Disaster risk reduction naturally takes preventive action seriously, advocating for more investment in preparedness and mitigation. This position has transformed the agenda from better managing disasters to reducing disaster risk. Flexibility, the ability to work within

Preliminary – Corrections Pending

complexity and the nimbleness to respond and incorporate large-scale shifts in global agendas are required now more than ever. In this spirit, greater collaboration is required between disaster risk reduction and peacebuilding and conflict prevention communities. The disaster risk reduction community should not be seen as a separate actor; rather disaster risk reduction should be integrated into the platforms and processes that exist in fragile and crisis settings (Peters, 2019).

International humanitarian law (IHL) is a set of rules which seek, for humanitarian reasons, to limit the effects of armed conflict. It protects persons who are not or are no longer participating in the hostilities and restricts the means and methods of warfare. International humanitarian law is also known as the law of war or the law of armed conflict. International humanitarian law is part of international law, which is the body of rules governing relations between States. International law is contained in agreements between States – treaties or conventions –, in customary rules, which consist of State practice considered by them as legally binding, and in general principles. International humanitarian law applies to armed conflicts. It does not regulate whether a State may actually use force; this is governed by an important, but distinct, part of international law set out in the United Nations Charter (ICRC, 2004).

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Coordinating agency or organisation

Not identified.

Preliminary – Corrections Pending

SO0102 / SOCIETAL / Conflict

Non-International Armed Conflict (NIAC)

Definition

It is widely accepted today that two key conditions must be met for a situation of violence to be considered a Non-International Armed Conflict (NIAC) and therefore subject to International humanitarian law (IHL): the non-state party/parties must be organized, and the violence between the parties must be sufficiently intense. The existence of a NIAC is not predicated on any other threshold or condition. In particular, political or other motivations of the parties play no role in the classification of a conflict. (adapted from ICRC, 2024)

Reference

ICRC, 2024, Opinion Paper, "How is the term 'armed conflict' defined in IHL?" https://www.icrc.org/sites/default/files/document_new/file_list/armed_conflict_defined_in_ihl.pdf Accessed 31 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Armed conflict not of an international character, Internal armed conflict, NIAC

Additional scientific description

Article 3 of the Geneva Conventions provides for "the case of armed conflict not of an international character," and the definition of Non-International Armed Conflict (NIAC) offered herein reflects the International Committee of the Red Cross (ICRC)'s understanding based on practice and international case-law (ICRC, 2016). The category of NIAC includes:

- Armed conflicts between a State Party and one or more organised non-State Parties (ICRC, 2016).
- Armed conflicts which do not include a State Party but are between two or more organised non-State Parties (UN, 1998).

Confrontations must occur between organised Parties possessing organised armed forces (ICRC, 2016). While NIAC occurs predominantly within a State, NIAC may feature extraterritorial aspects (ICRC, 2016) and/or become internationalised with the involvement of foreign States in support of one or more Parties (ICRC, 2016).

Armed violence must meet a minimum threshold of intensity that distinguishes it from situations not considered NIAC, including the following:

- "Internal disturbances and tensions, such as riots, isolated and sporadic acts of violence and other acts of a similar nature" (UN, no date; Article 1 of Additional Protocol II).
- "Banditry, unorganized and short-lived insurrections, or terrorist activities" (ICRC, 2016).

The intensity of violence is assessed on a case-by-case basis based on cumulative evidence relating to objective criteria, and the International Criminal Tribunal for the former Yugoslavia (ICTY) developed a non-exhaustive set of 'indicative factors' that can be used as examples to determine 'the seriousness of attacks' (ICTY, 2008).

In the view of the ICRC, the classical NIAC approach must be complemented by a support-based approach to third-party operations in pre-existing NIACs. The decisive element here is the third party's direct and effective contribution to the collective conduct of hostilities through the support it provides to the state(s) involved in the pre-existing NIAC (ICRC, 2024).

The termination of NIAC is also based on objective criteria and not the declaration of a ceasefire, armistice, or peace agreement. International humanitarian law "extends beyond the cessation of hostilities until…a peaceful settlement is achieved" (ICTY, 1995: para. 70). The termination of NIAC may be initiated when one of the Parties is summarily defeated and ceases to exist or

otherwise dissolves, or when there is a lasting absence of armed confrontations between the original Parties.

Metrics and numeric limits

The identification and classification of NIAC is not conducted by a central authority and the minimum threshold of intensity and duration for an armed confrontation to be considered a situation of NIAC is determined on a case-by-case basis (ICRC, 2016).

Academic conflict datasets are available; they provide their own operational thresholds for the minimum number of annual fatalities for NIAC events and trends to be included. For example, two of the most influential academic conflict datasets, the Uppsala Conflict Data Program (Uppsala Universitet, no date) and the Correlates of War (The Correlates of War Project, no date) apply annual conflict-related fatality thresholds of 25 and 1000, respectively. The Correlates of War seeks to facilitate the collection, dissemination, and use of accurate and reliable quantitative data in international relations. Key principles of the project include a commitment to standard scientific principles of replication, data reliability, documentation, review, and the transparency of data collection procedures.

Key relevant UN convention / multilateral treaty

Article 3 Common to the Geneva Conventions

- Geneva Convention Relative to the Protection of Civilian Persons in Time of War (Fourth Geneva Convention) (ICRC, 1949).
- 1977 Additional Protocol II to the Geneva Conventions of 1949 (ICRC, 1977).
- Rome Statute of the International Criminal Court (ICC) (last amended 2010) (UN, 1998).

Examples of drivers, impacts, and risk management

Hazard Drivers: The Global Platform underscored the security implications of climate change and disasters and encouraged more context-specific disaster risk reduction and resilience-building strategies in conflict-affected countries and fragile contexts based on risk assessments that integrate disaster, climate risks and conflicts (UNDRR, 2019).

Impacts: Armed conflict carries immediate and severe impacts on human lives, health, and dignity with increasing numbers of military personnel and civilians being killed, wounded, treated without dignity, arbitrarily detained and/or separated from their families. They may have been targeted on purpose, forced to leave their homes, and deprived of their basic rights as human beings, such as the right to supplies essential to their survival" (ICRC, 2023).

In situations of armed conflict, international humanitarian law aims to protect people, the environment, livelihoods, infrastructure, education systems, health systems, and cultural objects and property, to name a few. Impacts could include impacts from the use of biological agents (BI0602), chemical agents (CH0903), nuclear agents (TL0603) and explosive agents (TL0306). Additionally, explosive ordnance (explosives remnants of war) (SO0201) and environmental degradation from conflict (SO0202) may have impacts.

Multi-hazard Context: Since the 1970s, an emerging body of work has sought to deepen and nuance understanding of the construction of disaster risk, and the intersection of natural hazards with violence, conflict and fragility. The interplay between disasters, climate change, environmental degradation, and fragility should be recognized, including in the context of water-related risk (Peters, 2019).

The dynamic nature of systemic risks, new structures to govern risk in complex, adaptive systems and to develop new tools for risk-informed decision-making that allow human societies to live in and with uncertainty. This is particularly needed where environmental, health and financial systems, supply chains, information and communication systems are clearly vulnerable. These are challenged by, and are causal drivers of, disruptive influences such as climate change, loss of biodiversity and ecological systems degradation, disease outbreaks, food shortages, social unrest, political instability and conflict, financial instability and inequality. They also create vulnerability on multiple spatial scales (local to global) and across different timescales (from immediate to decadal and beyond) (UNDRR, 2019).

Disasters can also impact people who have already been forcibly displaced by conflict or other reasons (UNDRR, 2025).

Monitoring: Monitoring armed conflicts involves observing, tracking, and analyzing various aspects of conflict situations to understand their dynamics, impact, and potential for escalation or de-escalation. This can be done through various methods, including satellite imagery, field reports, and online portals, with the goal of informing decision-makers and promoting peace efforts.

Various mechanisms exist including the Geneva Academy Rule of Law in Armed Conflict Online Portal (RULAC) which classifies all situations of armed violence that amount to an armed conflict under international humanitarian law. Currently, it monitors more than 110 armed conflicts and provides information about parties, the latest developments, and applicable international law. Some of these conflicts make the headlines, others do not. Some of them started recently, while others have lasted for more than 50 years (Geneva Academy, no date).

Risk Management: Everyone has the right to protection against hazards, regardless of whether they live in a relatively peaceful and stable society, or one where challenges associated with violence, conflict and fragility are rife. Where these challenges exist,

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vulnerabilities are highest and capacities to manage disaster risk are often insufficient. For these reasons, conflict contexts require dedicated support for disaster risk reduction (Peters, 2019).

Disaster risk reduction naturally takes preventive action seriously, advocating for more investment in preparedness and mitigation. This position has transformed the agenda from better managing disasters to reducing disaster risk. Flexibility, the ability to work within complexity and the nimbleness to respond and incorporate large-scale shifts in global agendas are required now more than ever. In this spirit, greater collaboration is required between disaster risk reduction and peacebuilding and conflict prevention communities. The disaster risk reduction community should not be seen as a separate actor; rather disaster risk reduction should be integrated into the platforms and processes that exist in fragile and crisis settings (Peters, 2019).

International humanitarian law (IHL) is a set of rules which seek, for humanitarian reasons, to limit the effects of armed conflict. It protects persons who are not or are no longer participating in the hostilities and restricts the means and methods of warfare. International humanitarian law is also known as the law of war or the law of armed conflict. International humanitarian law is part of international law, which is the body of rules governing relations between States. International law is contained in agreements between States – treaties or conventions –, in customary rules, which consist of State practice considered by them as legally binding, and in general principles. International humanitarian law applies to armed conflicts. It does not regulate whether a State may actually use force; this is governed by an important, but distinct, part of international law set out in the United Nations Charter (ICRC, 2004).

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Coordinating agency or organisation

Not identified.

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SO0103 / SOCIETAL / Conflict

Civil Unrest

Definition

Civil unrest is an umbrella term for a wide spectrum of social and/or political phenomena, and although there is no commonly agreed definition, the term is used widely among United Nations agencies, funds and programmes.

A suggested definition for civil unrest is as follows: sporadic but continued collective physical violence in a context of social or political instability, that may result in deaths, injury and destruction. At times, non-violent collective action (such as protests, demonstrations, etc.) - exercising the right to peaceful assembly - or mass gatherings, when intersecting with external actors or factors, may lead to violence (Adapted from Kalyvas, 2000).

Reference

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Annotations

Synonyms

Terms often used as synonyms include social unrest, civil disorder, civil disobedience, violent disorder and civil disturbance, although this is not uniform as definitions and meanings vary depending on user group.

Additional scientific description

Despite wide use, there is no commonly used definition for 'civil unrest', although related terms, such as riot, terrorism, protest and violent disorder are defined in some national legislation. Academic and non-legal definitions are available, as outlined below. Some authors emphasise the explicit non-state affiliation in their definition of 'civil' unrest, while others are less clear about the state and non-state contribution. An important distinction is that civil unrest is largely understood to take place in times of peace (Kalyvas, 2000), although not exclusively as noted below by the International Committee of the Red Cross (ICRC). Instances of civil unrest can take place over short or long timeframes and are widely although not exclusively, understood to be urban acts (Kalyvas, 2000).

Everyone has the right to peaceful assembly, as enshrined by the Universal Declaration of Human Rights (Art. 20(1)) and the International Covenant on Civil and Political Rights (Art. 21), which imposes a corresponding obligation on States parties to respect and ensure its exercise, without discrimination (General Comment No. 37 (2020)).

While acts such as peaceful protests can have no or relatively minimal disturbance, violent riots can result in deaths, and destruction of property and infrastructure (Evans, 1993; Braha, 2012). In the case of civil unrest in Los Angeles in 1992, for example, violence resulted in 53 deaths, 2325 reported injuries and more than USD 735 million in damage to buildings (Evans, 1993).

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Civil unrest is generally understood to include violent and non-violent group acts such as riots, protests, and isolated and sporadic acts of violence (Braha, 2012; Basedau et al., 2018). The perceived or actual motivation for the act is often emphasised when describing collective action as civil unrest, alongside a clash with authority (Ramakrishnan et al., 2014). Frequently cited explanations include tension or dissatisfaction over political, economic or social changes/conditions (Kalyvas, 2000). According to Basedau et al. (2018:5), 'One can conceptualize civil unrest as a special form of collective action and people need to be motivated and able to exert it.' Braha (2012) defined civil unrest as a 'form of collective human dynamics, which has led to major transitions of societies in modern history', while Oncevay et al. (2020) defined it as 'public manifestations, where people demonstrate their position for different causes'.

According to Melzer (2009), as part of guidance from the International Committee of the Red Cross (ICRC) on International Humanitarian Law, civil unrest can also take place in times of armed conflict:

"During armed conflict, political demonstrations, riots, and other forms of civil unrest are often marked by high levels of violence and are sometimes responded to with military force. In fact, civil unrest may […] even benefit the general war effort of a party to the conflict by undermining the territorial authority and control of another party through political pressure, economic insecurity, destruction and disorder. It is therefore important to distinguish direct participation in hostilities – which is specifically designed to support a party to an armed conflict against another – from violent forms of civil unrest, the primary purpose of which is to express dissatisfaction with the territorial or detaining authorities."

Metrics and numeric limits

Given the lack of a single definition, there are no commonly agreed metrics or numerical limits for the term. Attempts have been made to forecast civil unrest using open-source indicators (such as Ramakrishnan et al., 2014), although the most commonly used conflict data sets do not define civil unrest. For example, the term is not commonly defined or used by the Armed Conflict Location & Event Data Project (ACLED, no date) or the Peace Research Institute Oslo (PRIO). ACLED does however offer definitions for different forms of violent and non-violent action which could all fall under the definition of civil unrest, such as protest and riot. Similarly, the Social Conflict Database (SCAD, 2017) does not provide a single definition for civil unrest but offers several definitions which may be classed as forms of civil unrest. These are: organised demonstration; spontaneous demonstration; organised violent riot; spontaneous violent riot; general strike; and limited strike.

Key relevant UN convention/multilateral treaty

While civil unrest has not been defined by UN conventions, several texts at global and regional levels are relevant with regard to guaranteeing the freedom of peaceful assembly, in particular the Universal Declaration of Human Rights and the International Covenant on Civil and Political Rights (General Comment No. 37 (2020)). There are also various texts detailing the limitations of the use of force by security forces, such as the UN Code of Conduct for Law Enforcement Officials (1979) and UN Basic Principles on the Use of Force and Firearms by Law Enforcement Officials (1990) (see also General Comment No. 36 (2019) on Art. 6 of the ICCPR (right to life).

Examples of hazard drivers, impacts and risk management

Hazard Drivers: Civil unrest may be triggered by the occurrence of various other hazards, or an ineffective or inefficient response to their occurrence, in particular in the case of other societal hazards, such as those involving violence, conflict or financial shock, but also various environmental, technological and other hazards.

Impacts: All kinds of civil unrest and protest activity remain a problem. Contributing factors such as high inflation, wealth inequality, food and fuel prices, climate anxieties and concerns about civil liberties or perceived assaults on democracy have not eased. Civil unrest has a wide range of negative impacts, affecting businesses, individuals, and the broader community. These impacts can include physical damage to property, economic losses, psychological distress, and a reduction in social engagement (Allianz, 2025).

Multi-hazard Context: Civil unrest in contemporary society, in much of the world, is reported to be evolving rapidly, likely contributing to current trends and having important implications for the direction of the trends going into the future. Rapid shifts that may be relevant to social and population health include the increasing ageing population, widespread adoption of remote working, increased automation, economic strain and inequity, migration and mobility, mental health crisis among youth, rise in xenophobia, civil and political unrest, and environmental crises, all of which may potentially exacerbate trends concerning social connection. These trends of declining social connection, combined with the evidence on the bidirectional associations with mental and physical morbidities, point to an urgent need to take action. Because multiple factors have been contributing to these trends, building over decades, simply returning to pre-pandemic levels of connection or reducing time on social media may only bring limited benefits (Holt-Lunstad, 2024).

Monitoring: Within the United Nations system, various treaty-based and UN Charter-based human rights monitoring mechanisms

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are relevant to contexts where civil unrest may occur, and early warning signs can be identified. The charter-based bodies include the Human Rights Council, Special Procedures (currently including 45 thematic mandates and 13 country mandates), the Universal Periodic Review and Independent Investigations. Treaty bodies include the Committee on the Elimination of Racial Discrimination (CERD), Committee on Economic, Social and Cultural Rights (CESCR), Human Rights Committee (CCPR), Committee on the Elimination of Discrimination against Women (CEDAW), Committee against Torture (CAT), Committee on the Rights of the Child (CRC), Committee on Migrant Workers (CMW), Subcommittee on Prevention of Torture and other Cruel, Inhuman or Degrading Treatment or Punishment (SPT), Committee on the Rights of Persons with Disabilities (CRPD), and Committee on Enforced Disappearances (CED). Various early warning systems also exist at regional levels, including under the frameworks of the African Union, the Organization of American States, and the Council of Europe.

Risk Management: Documented operational risk management for civil unrest includes preparedness and response. The public health sector offers frameworks for violence prevention interventions as well as responses, as documented by the World Health Organization (Krug et al., 2002).

Widespread civil unrest, with mass gatherings of protestors, has in some instances resulted in criminal damage and business disruption. Protests are by nature unpredictable, but steps can be taken by organisations to help mitigate the risk. Suggested steps might include reviewing work practices if protests are anticipated and asking staff to avoid going into areas where protests may occur, possibly switching to virtual meetings and to considering rescheduling any planned events (Ecclesiastical, 2024).

Successful outcomes are generally regarded as cessation of physical violence and restoration of civil rights.

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Coordinating agency or organisation

Not Identified.

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SO0201 / SOCIETAL / Post-Conflict

Explosive Ordnance

Definition

Explosive ordnance, including explosive remnants of war, is interpreted as encompassing the following munitions: mines, cluster munitions, unexploded ordnance, abandoned ordnance, booby traps and other devices (IMAS 4.10) that remain in the environment following the cessation of armed conflict.

Explosive remnants of war refer to unexploded ordnance and abandoned explosive ordnance that are left by a party to an armed conflict following the cessation of warfare. Unexploded ordnance are munitions that have been primed, fused, armed or otherwise prepared for use, and may have been fired, dropped, launched or projected yet remain unexploded through malfunction or design or for any other reason. Abandoned ordnance refers to explosive ordnance that has not been used during an armed conflict but has been left behind or dumped. Mines are munitions designed to be placed under, on or near the ground or other surface area and to be exploded by the presence, proximity or contact of a person or a vehicle.

Reference

United Nations Mine Action Service, 2024. International Mine Action Standards 01.10 (IMAS 04.10) Glossary of mine action terms, definitions and abbreviations International https://www.mineactionstandards.org/fileadmin/uploads/imas/Standards/English/IMAS_04.10_Ed.2_Am.12.pdf Accessed 14 February 2025.

Annotations

Synonyms

Unexploded ordnance, Abandoned explosive ordnance. Explosive Remnants of War, ERW. (sp) restos explosivos de guerra; munitcones sin detonar. (Fr) Restes explosifs de guerre.

Additional scientific description

The United Nations (2004) definition provided above is from Protocol V of the Convention on Certain Conventional Weapons but does not include any reference to explosive remnants of war (ERW) in the form of improvised explosive devices. However, these are mentioned as 'other devices' in amended Protocol II to the Convention on Certain Conventional Weapons.

'Explosive ordnance is a catchall term for any explosive ordnance that remains unexploded and abandoned following the cessation of conflict. An explosive ordnance may be considered 'unexploded' or 'abandoned' if it has been "primed, fused, armed, or otherwise prepared for use […] in an armed conflict" prior to being "left behind or dumped by a party to an armed conflict" (United Nations, 2004:2).

As of October 2024, at least 58 states and other areas (i.e., Abkhazia, Nagorno-Karabakh, Somaliland) were known or suspected to be anti-personnel landmine contaminated, while 26 states and 2 other areas had cluster munitions contamination, as of 31 December 2023 (Landmine & Cluster Munition Monitor, 2024a, b). A recent study examining explosive ordnance in over 100,000 casualties across 17 countries and other areas found a case fatality rate of 38.8 per 100 persons injured (Pizzino, 2024).

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Cluster munitions are an example of ERW and have a long history of conventional use by state actors during warfare (UNODA, 2020a). They are "designed to cover an area with explosive force" and have been used in warfare since the Second World War (Bolton & Nash, 2010:175). A cluster munition produces damage by exploding a single projectile, which fragments into a number of smaller explosive ordnance, which then detonate over a large area (Bolton & Nash, 2010:175). Cluster munitions are of particular concern when discussing the impact of ERW, as the impact of unexploded cluster munitions when detonated is significantly higher than other conventional munitions. A study of the comparative impact on civilian populations found that "ten unitary projectiles with a 10 per cent failure rate will leave one unexploded item whereas ten cluster munitions with 100 submunitions each and a 10 per cent failure rate will leave 100 unexploded items – ten times as many" casualties or fatalities (Bolton & Nash, 2010:175). The clearance of cluster munitions has proved extremely challenging in many contexts – for example in Kosovo (ICRC, 2001:18) and Lao PDR, (UNDP Lao PDR, 2009) where civilians who went in search of provisions such as firewood accidentally detonated the munitions, causing many casualties and fatalities.

Explosive remnants of war also have adverse effects on populations owing to the shedding of chemicals or chemically active compounds into areas where they are abandoned. This can have long-term effects when a population is exposed to the chemicals through contamination of water, soil, food sources, and general living environment. One such example is the presence of depleted uranium, which has had significant impacts on the health of conflict-affected populations and their environment since it was introduced into conventional warfare (UNODA, 2020b). Depleted uranium has a high density, which makes it a useful component of kinetic energy weapons such as anti-tank weaponry (Murray et al., 2002). In areas with high radioactive contamination, there is a risk of wildfires burning terrain leading to an uncontrolled re-distribution of radioactive particles – which has a profound negative impact on population health. This has resulted in depleted uranium weapons being used widely with the exploded particle remnants being inhaled by those working and living in the vicinity of the conflict (Murray et al., 2002). The long-term effects of exposure to the remnants of depleted uranium from a health perspective are still unclear, but the environmental impact is profound – with an increase in uranium in water supplies, contaminated soil, and potentially unexploded remnants of depleted uranium munitions (Murray et al., 2002).

Metrics and numeric limits

Not available.

Key relevant UN convention / multilateral treaties

The Convention on Cluster Munitions (2008) (Daj Hammarskjold Library, 2020); the Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on their Destruction (1997) (Daj Hammarskjold Library, 2020); and the Convention on Certain Conventional Weapons (CCW) (1980) (Daj Hammarskjold Library, 2020).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Explosive ordnances may be disseminated during floods and landslides (Baselt et al., 2023). Flooding can cause erosion of soil, potentially uncovering and carrying away previously buried ERWs, increasing the risk of contaminating new areas, or re-contaminating areas previously cleared (Njeri & Greene, 2024). Stockpiles of munitions may also explode during extreme heat events (Small Arms Survey, 2025)

Impacts: Explosive remnants of war have a profound impact on civilian populations and their environment well after the end of a conflict. Civilians in areas with ERW embedded in their environment are at risk of becoming casualties of explosive ordnance, potentially losing limbs or their lives (UNODA, 2020c). The presence of ERW restricts the movement of populations and hinders reconstruction, resulting in potentially limited access to arable land, food, water, care or trade (UNODA, 2020c).

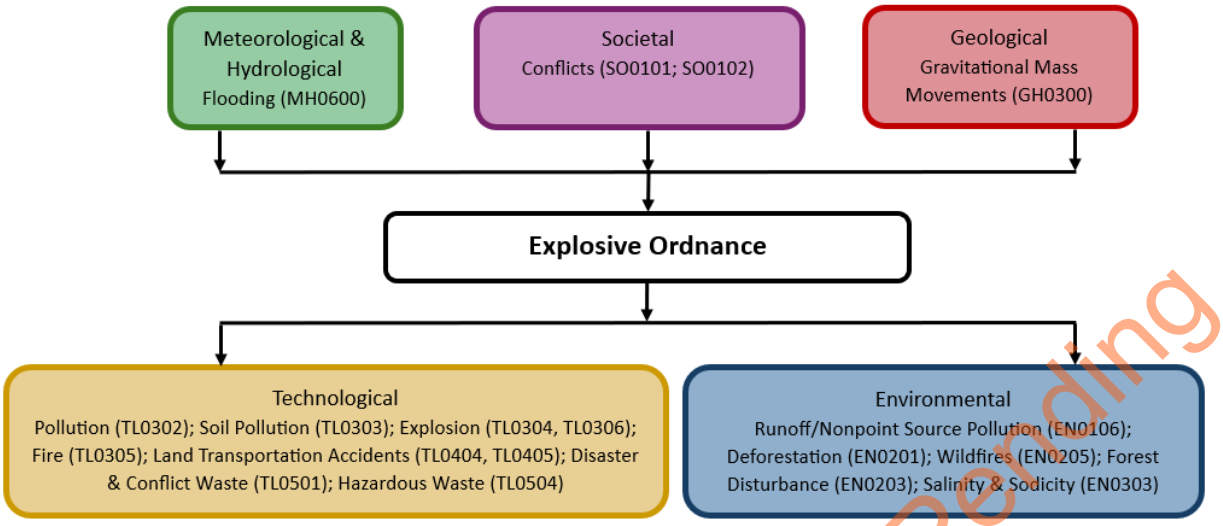
Explosive remnants of war have an impact on the quality of water sources and arable land, as particulate matter from these remnants may infiltrate the environment – as in the case of depleted uranium weaponry (Murray et al., 2002). Explosive remnants of war pose a threat to people's health and human rights in more than 60 lower- and middle-income countries (Frost et al., 2017). From 1999 through 2023, 159,445 mine and ERW casualties have been recorded, and 24,502 cluster munitions casualties have been recorded to the end of 2023. Annual casualty numbers have risen in recent years with at least 28,957 persons killed or injured by mines and ERW across 2019 – 2023 (Landmine & Cluster Munition Monitor, 2024a, b). Although the exact number of survivors is unknown, many develop subsequent long-term psychological and physical sequelae (Frost et al., 2017). The wider long-term effects of ERW are a social and economic burden to victims, their families, the wider at-risk community, and health systems (Frost et al., 2017).

For civilians and communities in war-affected countries, the presence of these weapons represents an ongoing threat. Many innocent civilians have lost life or limb by disturbing or inadvertently coming into contact with explosive remnants of war. These weapons can also hinder reconstruction efforts and threaten people's livelihoods. Homes, hospitals and schools cannot be rebuilt – and contaminated land cannot be farmed – until such weapons are cleared (ICRC, no date).

Multi-hazard Context: The figure below summarises common interactions between explosive ordnance and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not

Preliminary – Corrections Pending

necessarily cause, amplify or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: Not Applicable

Risk Management: Protocol V of the Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons outlines the following control measures to mitigate the impact of ERW: survey and assess the threat posed by ERW in a post-conflict situation; assess and prioritise needs for the marking and removal/clearance of ERW; and clear/remove the ERW where possible and safe (United Nations, 2004:3).

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Coordinating agency or organisation

Not identified.

Preliminary – Corrections Pending

SO0202 / SOCIETAL / Post-Conflict

Environmental Degradation from Conflict

Definition

Environmental degradation is both a driver and consequence of disasters and conflict, reducing the capacity of the environment to meet social and ecological needs (Adapted from UNDRR, 2022).

Reference.

UNDRR, no date. Environmental degradation United Nations Office for Disaster Risk Reduction (UNDRR) https://www.preventionweb.net/understanding-disaster-risk/risk-drivers/enviromental-degradation Accessed 30 May 2025.

Preliminary – Corrections Pending

Annotations

Synonyms

Ecological degradation, Environmental damage, Toxic remnants of war, War-related pollution, Ecological war impacts. (sp) Degradcion ecologica, Contaminacion ambiental por guerra

Additional scientific description

The types of human-induced degradation are varied and include land misuse, soil erosion and loss, desertification, wildland fires, loss of biodiversity, deforestation, mangrove destruction, land, water and air pollution, climate change, sea-level rise and ozone depletion (UNISDR, 2009:6).

Environmental degradation occurs during peacetime but can be particularly exacerbated by an armed conflict. The level of environmental damage from conflict depends on several factors: the weapons as well as the tactics used; location of the military operations (e.g. rural vs urban, proximity to industrial sites), the duration of the military conflict (Jensen, 2019) and the pre-war environmental conditions (Biswas, 2000). In parallel, countries might enter the vicious cycle between environmental degradation and conflict as pollution and environmental hazards can on the other hand undermine security and lead to political instability, disasters and regional tensions (Conca & Wallace, 2009).

Metrics and numeric limits

As an example of metrics, the Conflict and Environment Observatory CEO (2021) reported that Deforestation is an ongoing concern in many conflict-affected and post-conflict countries, with many of the drivers linked either directly or indirectly to the conflict. In 2020, there was a sharp increase in forest loss in most conflict-affected countries, which in some can be tentatively linked to COVID-19, either through economic hardship or organised crime taking advantage of distracted institutions. In total, and across all conflict-affected areas assessed, forest loss increased by 10% in 2020 to 3.2 million hectares (CEO, 2021).

Key relevant UN convention / multilateral treaty

International Humanitarian Law, International Criminal Law, International Environmental Law, and International Human Rights Law, including provisions protecting the environment in conflicts. In 2019, the International Law Commission Drafting Committee provisionally endorsed 28 legal principles intended to mitigate environmental degradation before, during and after conflicts (International Law Commission, 2022).

The Hague Convention IV of 1907 and Additional Protocol I to the Geneva Conventions (AP I)

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Not Applicable

Impacts: The impact of conflicts on the environment is three-fold: direct impact, secondary impact, and environmental governance impact and increases any other degradation for other natural hazards such as landslides due to deforestation.

Direct impact includes intentional targeting of the environment, physical destruction, or the use of natural resources by militant groups to finance conflict, environmental contamination from bombing of industrial sites, and military debris and demolition waste from targeted infrastructure (Solomon et al., 2018; Jensen, 2019). Modern military confrontation may involve exposure to toxic substances and substances of uncertain toxicity, such as depleted uranium used in munition. Large amounts of depleted uranium may remain deposited in soil after the end of the military operations. It represents a significant hazard due to potential contamination of air, soil and water (Murray et al., 2002). Furthermore, conflict can impact the environment regionally (Hopke, 2009).

Secondary impact results from the coping strategies used by the population to survive in conflict, such as overuse of natural resources, environmental damage due to population displacements, growth of a black market for natural resources during conflict, and implementation of large-scale humanitarian and peacekeeping operations without due consideration to environmental impact (Jensen, 2019).

Third, military conflicts frequently weaken environmental governance structures, and hinder policy coordination, investment and the enforcement of the law (UNEP, 2009; Bruch, 2019; Jensen 2019). The financial resources and technical equipment usually utilised for environmental law enforcement can be redirected to war needs (Bruch, 2019). The breakdown of environmental governance is potentially the most challenging impact to address (Bruch et al., 2016; Jensen, 2019). The consequences are long-term, persistent, and affect larger territories than direct impact (Jensen, 2019). For instance, conflicts are generally known to have negative direct and secondary impacts on biodiversity (Solomon et al., 2018). However, a study at UC Berkley suggested that during armed conflicts, institutional collapse kills even more wildlife than military tactics (Gaynor et al., 2016). The CEOBS (Conflict and Environment Observatory) 2024 report highlights how ecosystem collapse can lead to long-term environmental crises and exacerbate existing conflicts. Specifically, the report examines how significant environmental damage to agricultural land and other sensitive infrastructure potentially leads to further resource scarcity and conflict (CEOBS, 2024).

Nevertheless, the impact of environmental damage in conflicts on human lives and health is still poorly documented and addressed in conflict resolution and humanitarian assistance but increasing evidence is collected and analysed (Pizzino et al., 2023; Meaza et al., 2024; CEBOS, https://ceobs.org, no date).

Multi-hazard Context: The relationship between climate change, conflict and displacement is complex and context-specific – over-simplification may lead to inappropriate or ineffective action (UNFCCC, 2022). Compounded droughts, flooding, locust plagues, environmental degradation, and poor governance are all leading to an increasingly precarious and complicated situation for tens of millions of people. For example, cascading disasters in many parts of the world, including throughout Africa, and the Arid Corridor in the Americas, are exacerbating other trends such as urbanisation and the abandonment of small farm holdings (UNFCCC, 2022).

As an example of technological impacts on the environment from conflict, in the first Gulf War, when 700 of Kuwait's oil fields were set ablaze, the smoke plume initially stretched for 800 miles. In addition, approximately 11 million barrels of crude oil poured into the Persian Gulf, creating a slick nine miles long. Inland, nearly 300 oil lakes formed on the surface of the desert, polluting the soils for decades. An international coalition of firefighters fought the fires for months until the last well was finally capped in November 1991. Even now, more than 30 years later, the effects of those fires are still felt, with more than 90 per cent of the contaminated soil still exposed (UNFCCC, 2022).

Monitoring: Not Applicable

Risk Management: Protection of the environment during a military conflict has the potential to facilitate peacebuilding (Conca & Wallace, 2009), or in case of failure to respond, can hinder further peacebuilding efforts (Jensen & Lonergan, 2012). Assurance of implementation of international law, training of military personnel (including revision of military training manuals regarding the protection of the environment in conflict), and integration of environmental considerations including biodiversity conservation into military, reconstructions and humanitarian programmes in conflict areas, are some of the measures that can help mitigate environmental damage from conflict.

Remedying the environmental impacts of war is complex and reparations are still a challenge (Kong et al., 2023).

Preliminary – Corrections Pending

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Coordinating agency or organisation

Not identified.

Preliminary – Corrections Pending

SO0301 / SOCIETAL / Behavioural

Violence

Definition

Violence is a social phenomenon that involves forceful acts or behaviour that are intended to cause harm. The injury or damage inflicted by violence to an individual or collective group may be physical, psychological, sexual, or deprivation, or combined. Violence is both intentional and forceful (Adapted from Jacquette, 2013).

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Preliminary – Corrections Pending

Annotations

Synonyms

Not identified.

Additional scientific description

The World Health Organization categorises violence as: self-directed, interpersonal and collective. All three categories of violence can have a societal impact whether directly or indirectly (WHO, 2002). According to Galtung (1969, 1996), violence can also be direct, structural, and cultural. There are several forms and typologies of violence. These are characterised here on the basis of the motives, target groups and tactics of violence:

Violence can either be targeted or indiscriminate, motivated by certain aims, including political, religious, social, economic, ethnic, racial, or gender-based, or unintentional and can be initiated with the aim to directly or indirectly inflict harm, injury or death (Krug et al., 2002). Violence has been explicitly identified as a significant public health problem (Rutherford et al., 2007).

Motives: Political violence is defined as hostile, aggressive or violent acts motivated by political objectives or a desire to directly or indirectly affect political change or change in governance. As a phenomenon, political violence may include a range of political acts from riots, coups, rebellions, uprisings and terrorism to violent acts committed by state and non-state actors, including pogroms, ethnic cleansing, and genocide (Kalyvas, 2013; Balcells, 2015). However, everyone has the right to peaceful assembly, as enshrined by the Universal Declaration of Human Rights (Art. 20(1)) and the International Covenant on Civil and Political Rights (Art. 21), which imposes a corresponding obligation on States parties to respect and ensure its exercise, without discrimination (General Comment No. 37 (2020)).

While radicalisation, by definition, does not involve the use of violence, it refers to a process, often a multidimensional, complex and long-term process, by which individuals are introduced to extremist ideologies that motivate them to defy and challenge the status quo. This often leads to the eventual adoption of violence. Violent extremism refers to “the willingness to use or support the use of violence” or terror as an appropriate means to achieve ideological, social or political objectives (Elshimi, 2018; Mansour-Ille, 2019).

Religious violence refers to violent acts committed by either state or non-state actors and motivated by religious convictions, ideologies or belief systems. Religious violence is closely associated with radicalism and religious extremism and refers to acts ranging from inciting violence against particular religious groups, discrimination or segregating certain religious groups, persecution, genocide, random physical aggression, gang or mob violence and defaming or injuring verbal abuse or violence (Clarke, 2011).

Ethnic or racial violence refers to violence between different groups of people on the basis of ethnic or racial differences or differences in culture, religion or language motivated by ethnic or racial diversity. Violent acts motivated by ethnic or racial

differences take many forms, ranging from segregation and institutionalised discrimination to genocide, ethnic cleansing, pogroms, civil wars and violent separatist movements (Bergmann & Crutchfield, 2009; Rutherford & Bar-Yam, 2010).

Social violence (also referred to as societal violence) refers to any type of violence employing physical or emotional acts of aggression committed by individuals or a community of individuals with the aim to have a social or societal impact or cause serious physical and emotional harm to a group of people or to society as a whole. These acts can be direct or indirect and can take various forms across countries varying from targeted social discrimination, segregation, terrorism, and physical aggression to gang violence. The Convention on the Elimination of All Forms of Discrimination against Women (CEDAW) (1979) refers to various forms of discriminatory acts on the basis of gender, which may impair or nullify "the recognition, enjoyment or exercise by women" of their basic human rights and fundamental freedoms equal to men "in the political, economic, social, cultural, civil or any other field" (Art. 1). Social violence can also be politically motivated (Kelly, 2014).

Forms of violence: The forms of violence include injury or damage inflicted to an individual or collective group may be physical, psychological, sexual, or deprivation, or combined

Gender-based violence is defined as acts or threats of acts intended to cause harm, injury, physical, sexual or psychological suffering to individuals and groups on the basis of their gender, such as women or LGBTIQ+ communities. It is defined by the UN Declaration on the Elimination of Violence against Women (1993) as "any act of gender-based violence that results in, or is likely to result in, physical, sexual or psychological harm or suffering to women, including threats of such acts, coercion or arbitrary deprivation of liberty, whether occurring in public or in private life" (Art. 1). Gender-based violence is also used in the context of domestic violence or intimate partner violence and can result in various forms of abuse and exploitation, including economic exploitation. A form of gender-based violence is sexual violence and exploitation, which refers to any form of abuse or exploitation that is sexually motivated targeting vulnerable groups, particularly women and children. Convention C190 of the ILO (2019) defines gender-based violence as violence and harassment "directed at persons because of their sex or gender or affecting persons of a particular sex or gender disproportionately and includes sexual harassment" (Art. 1b).

Child abuse, violence and exploitation refer to acts of violence, cruel or harmful treatment of a minor for profit, labour, sexual gratification, vengeance or other personal or financial gains (WHO). The Convention on the Rights of the Child (CRC) (1989) explicitly prohibits "all forms of physical or mental violence, injury or abuse, neglect or negligent treatment, maltreatment or exploitation, including sexual abuse, while in the care of parent(s), legal guardian(s) or any other person who has the care of the child" (Art. 19.1).

Terrorism refers to acts (a) committed with the intention of causing death or serious bodily injury, or the taking of hostages; (b) committed for the purpose of provoking a state of terror, intimidating a population, or compelling a Government or international organization to do or abstain from doing any act; and (c) constituting offences within the scope of and as defined in the international conventions and protocols relating to terrorism.

Psychological violence refers to any intentional or unintentional conduct that aims to cause serious emotional or psychological harm to another person (European Institute for Gender Equality, 2017). The Istanbul Convention (2011) outlines examples of such acts to include verbal aggression, coercive threats and intimidation, control, harassment or stalking, insults, humiliating and defaming conducts as well as acts that render another person isolated from family, friends and any sort of support. Such acts mainly occur in interpersonal relationships, such as familial, parental or intimate partner relationships (Council of Europe, 2014).

Torture is defined in the Convention against Torture (CAT) (1984) as "any act by which severe pain or suffering, whether physical or mental, is intentionally inflicted on a person for such purposes as obtaining from him or a third person information or a confession, punishing him for an act he or a third person has committed or is suspected of having committed, or intimidating or coercing him or a third person, or for any reason based on discrimination of any kind, when such pain or suffering is inflicted by or at the instigation of or with the consent or acquiescence of a public official or other person acting in an official capacity" (Art. 1.1).

The prohibition against torture and other forms of ill-treatment is embodied in several international human rights treaties and declarations, including the Universal Declaration of Human Rights (UDHR) (Art. 5, 1948), the International Covenant on Civil and Political Rights (ICCPR) (Art. 7, 1966), and the Convention against Torture and Other Cruel, Inhuman or Degrading Treatment or Punishment (1984). Several regional human rights treaties also uphold and reaffirm the prohibition against torture and other forms of ill-treatment, including: The European Convention for the Protection of Human Rights and Fundamental Freedoms (ECHR) (Art. 3, 1950), the American Convention on Human Rights (ACHR) (Art. 5, 1969), the African Charter on Human and Peoples' Rights (ACHPR) (Art. 5, 1981), the Inter-American Convention to Prevent and Punish Torture (1985), and the European Convention for the Prevention of Torture and Inhuman and Degrading Treatment or Punishment (1987).

Cruel, inhumane and degrading treatment refers to ill-treatment, which is premeditated and applied for prolonged periods of time that amounts to be cruel, inhumane and violating human dignity aimed at causing bodily injury, harm or intense physical and mental suffering (European Court of Human Rights, 2000).

Preliminary – Corrections Pending

Gang-related violence refers to violence that is perpetrated by a group of people who associate themselves with what can be referred to as a 'gang' – a relatively well-defined, durable and predominately street-based group of young people dominating a particular territory and known to the wider community (UK Government, 2016). Organised crime, on the other hand, refers to violent crimes or criminal activities committed by a group of people in an organised manner for profit using coercion, retaliation and extortion (NCA, 2020). Organised crimes are not confined to particular territories or borders.

Metrics and numeric limits

In 2019 an estimated 475,000 people worldwide were victims of homicide (global rate of 6.2 per 100,000). Rates in high-income countries/areas are generally lower than rates in low- and middle-income countries/areas. Some 80% of homicides occur in males and the highest rates are in males aged 15-29 years. Estimates are not calculated for countries with populations under 90,000 in 2019 or WHO non-Member States (WHO, no date b).

Estimates published by WHO indicate that globally about 1 in 3 (30%) of women worldwide have been subjected to either physical and/or sexual intimate partner violence or non-partner sexual violence in their lifetime (WHO, 2024).

Most of this violence is intimate partner violence. Worldwide, almost one third (27%) of women aged 15-49 years who have been in a relationship report that they have been subjected to some form of physical and/or sexual violence by their intimate partner (WHO, 2024).

Key relevant UN convention / multilateral treaty

Several international texts are of relevance and include the Universal Declaration of Human Rights, the UN Declaration on the Elimination of Violence against Women; the Convention on the Elimination of All Forms of Discrimination against Women; the Convention against Torture and Other Cruel, Inhuman or Degrading Treatment or Punishment; the Convention on the Rights of the Child; the Istanbul Convention; the International Convention on the Elimination of All Forms of Racial Discrimination, the International Covenant on Civil and Political Rights, the International Covenant on Economic, Social and Cultural Rights, the International Convention on the Protection of the Rights of All Migrant Workers and Members of Their Families, the International Convention on the Rights of Persons with Disabilities, the International Convention for the Protection of All Persons from Enforced Disappearance, and the Convention on the Prevention and Punishment of the Crime of Genocide and Convention C190 (ILO Violence and Harassment Convention).

A number of international conventions address the prohibition of, and response to, specific violent acts, e.g. Convention on Offences and Certain Other Acts Committed On Board Aircraft (Tokyo Convention), Convention for the Suppression of Unlawful Seizure of Aircraft (Hague Hijacking Convention) and additional protocol, Convention for the Suppression of Unlawful Acts against the Safety of Civil Aviation (Montreal Convention) and additional protocols, International Convention against the Taking of Hostages, Convention for the Suppression of Unlawful Acts against the Safety of Maritime Navigation (SUA Convention) and additional protocols, International Convention for the Suppression of Terrorist Bombings, International Convention for the Suppression of the Financing of Terrorism, International Convention for the Suppression of Acts of Nuclear Terrorism, Convention on the Suppression of Unlawful Acts Relating to International Civil Aviation (Beijing Convention).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: violence may be triggered by different situations and hazards. Yet, violence can be prevented. Interventions to address violence are delivered as part of a four-step public health approach that includes: defining the problem; identifying causes and risk factors; designing and testing interventions; and increasing the scale of effective interventions (WHO, 2024).

Preventing injuries and violence will facilitate the achievement of several Sustainable Development Goal (SDG) targets (WHO, 2024b).

Impacts: Globally, some 470,000 homicides occur each year and millions of people suffer violence-related injuries. Beyond death and injury, exposure to violence can increase the risk of alcohol and drug abuse; mental illness and suicidality; chronic diseases like heart disease, diabetes and cancer; infectious diseases, such as HIV, and social problems, such as crime, and further violence. Yet, violence can be prevented. Interventions to address violence are delivered as part of a four-step public health approach that includes: defining the problem; identifying causes and risk factors; designing and testing interventions; and increasing the scale of effective interventions (WHO, 2024).

Multi-hazard Context: Armed as well as non-armed forms of violence can occur both in non-conflict and conflict settings (Rutherford et al., 2007), including Non-International Armed Conflict (NIAC, in which one or more non-State armed groups are involved, and where protracted armed violence is taking place, meaning a certain intensity of the armed violence, and the actors taking part in it exhibit a certain degree of organization). Situations of internal disturbances or tensions such as riots, isolated and sporadic acts of violence, and other analogous acts are not considered armed conflicts. Nevertheless, the type of violence exerted by armed entities in certain contexts can be as egregious as found in international wars or NIAC. While the application of NIAC cannot be considered in these cases as the other conditions are not met, this does not diminish the gravity of the acts committed or the responsibility of stakeholders in their respective normative frameworks.

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Violence may also occur in association with other hazards, including societal hazards such as civil unrest escalating into ethnic violence, international armed conflict (IAC), civil unrest, stampede, or technological hazards such as cyberbullying, deliberate use of explosions or explosive agents.

Monitoring: Within the United Nations system, various treaty-based and UN Charter-based human rights monitoring mechanisms are relevant to contexts where violence occurs, and early warning signs can be identified.

Risk Management: The charter-based bodies include the Human Rights Council, Special Procedures (including 45 thematic mandates and 13 country mandates), the Universal Periodic Review and Independent Investigations. Treaty bodies include the Committee on the Elimination of Racial Discrimination (CERD), the Committee on Economic, Social and Cultural Rights (CESCR), the Human Rights Committee (CCPR), the Committee on the Elimination of Discrimination against Women (CEDAW), the Committee against Torture (CAT), the Committee on the Rights of the Child (CRC), the Committee on Migrant Workers (CMW), the Subcommittee on Prevention of Torture and other Cruel, Inhuman or Degrading Treatment or Punishment (SPT), the Committee on the Rights of Persons with Disabilities (CRPD), and the Committee on Enforced Disappearances (CED). Various early warning systems also exist at regional levels, including under the frameworks of the African Union, the Organization of American States, and the Council of Europe.

The United Nations Global Counter-Terrorism Strategy (A/RES/60/288), adopted by the UN General Assembly by consensus in 2006, provides a common strategic and operational approach to fighting terrorism, including preventive measures.

As a more detailed example of risk management WHO reports that there is growing evidence on what works to prevent violence against women, based on well-designed evaluations. In 2019, WHO and UN Women with endorsement from 12 other UN and bilateral agencies published *RESPECT Women* - a framework for preventing violence against women aimed at policymakers (WHO, 2024). Each letter of RESPECT stands for one of seven strategies: Relationship skills strengthening; Empowerment of women; Services ensured; Poverty reduced; Enabling environments (schools, workplaces, public spaces) created; Child and adolescent abuse prevented; and Transformed attitudes, beliefs and norms (WHO, 2024).

For each of these seven strategies, there are a range of interventions in low- and high-resource settings with varying degrees of evidence of effectiveness. Examples of promising interventions include psychosocial support and psychological interventions for survivors of intimate partner violence; combined economic and social empowerment programmes; cash transfers; working with couples to improve communication and relationship skills; community mobilization interventions to change unequal gender norms; school programmes that enhance safety in schools and reduce/eliminate harsh punishment and include curricula that challenge gender stereotypes and promote relationships based on equality and consent; and group-based participatory education with women and men to generate critical reflections about unequal gender power relationships (WHO, 2024).

RESPECT also highlights that successful interventions are those that prioritize the safety of women; whose core elements involve challenging unequal gender power relationships; that are participatory; address multiple risk factors through combined programming and that start early in the life course (WHO, 2024).

To achieve lasting change, it is important to enact and enforce legislation and develop and implement policies that promote gender equality; allocate resources to prevention and response; and invest in women's rights organizations (WHO, 2024).

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Coordinating agency or organisation

Not identified.

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SO0302 / SOCIETAL / Behavioural

Stampede or Crushing (Human)

Definition

Stampede or crushing is the surge of individuals in a crowd, in response to real or perceived danger or loss of physical space. It often disrupts the orderly movement of crowds resulting in movement for self-protection leading to increased localised crowd density and physical compression of the human bodies (Adapted from Burkle & Hsu, 2011; Illiyas et al., 2013; Ngai, et al., 2009).

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Annotations

Synonyms

Crush, Mass panic, Crowd disaster, Trampling, Crowd quakes, Mass-crowded stampede, Trampling accident.

Additional scientific description

Mass gatherings can be defined as a concentration of people at a specific location for a specific purpose over a set period of time, and which has the potential to strain the planning and response resources of the country or the community (WHO, 2015). With population growth and a constant increase in human mobility, mass gatherings are becoming more frequent and attract increasing numbers of participants (Johansson et al., 2012).

Mass gatherings are either spontaneous, such as at train stations during rush hour (Johansson et al., 2012) or are planned, such as sporting events, cultural events, music festivals, religious pilgrimages, or political events (WHO, 2015). The Hajj pilgrimage in Saudi Arabia and the Kumbh Mela in India are the biggest regular mass gatherings globally, bringing millions of pilgrims together (Ahmed et al., 2006; Illiyas et al., 2013). Mass gatherings may affect health in different ways and crowd disasters may occur, including the collapse of infrastructure, fire incidents, terrorist attacks, violent riots, and human stampedes (Soomaroo & Murray, 2012; WHO, 2015; Still, 2019) causing loss of lives. Stampedes resulting in crushing, carry high mortality rates and are, besides heat-related illnesses, the most common cause of mortality in mass gatherings (Steffen et al., 2012; Still, 2019).

Most crush casualties result in traumatic asphyxia caused by external compression of the thorax and/or upper abdomen, resulting in partial or complete cessation of respiration. It has been reported that significant compression forces can be present with even moderate crowds; forces of up to 4500 N (1000 lb) can be generated by just six to seven people pushing in a single direction with forces large enough to bend steel railings (Ngai et al., 2009).

Although survivors of human stampedes and autopsy reports suggest traumatic asphyxia as the primary cause of death, other

mechanisms have been considered, including myocardial infarction, direct crushing injury to intrathoracic or intraabdominal organs, head injury, and neck compression. All these mechanisms are possible; however, little actual supportive evidence exists. It has been concluded from autopsy findings that "people who succumb.... typically die (standing up) in a vertical position" due to compression force and "do not collapse to the floor until after the crowd density and pressure have been relieved. Compressive forces applied front to back or vice versa resulted in ventilatory failure, whereas those experiencing compressive forces from side to side were spared, presumably because chest expansion was not compromised to the same extent" (Ngai et al., 2009).

The full spectrum of injuries – including fractures, dislocations, and other mechanical injuries – may be expected. Among survivors, many may suffer from posttraumatic stress, grief, or survivor guilt and require psychological counselling or intervention (Ngai et al., 2009).

Metrics and numeric limits

There is no standardised metric to measure the impact of stampedes. However, there is much debate as to how to categorise stampedes, some academics think they should be categorised by the number of reported deaths as a result of the incident, whilst others think the number of injuries or fatality rates should be considered

Key relevant UN convention / multilateral treaty

International Health Regulations (2005) (WHO, 2016).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Much of what is reliably known about mass-gathering disasters is derived from post-event inquiries. Anecdotal news reports and observations also provide information on events. Frequently reported factors that trigger a stampede include rumours of a threat, sudden loud sounds, narrow passage and overcrowding.

Most stampedes occur indoors, during daytime hours, and in sports events (Hsieh et al., 2009)

Impacts: In recent decades, the toll from human stampedes has been increasingly well documented. Although there appears to be an uptick in the occurrence of deadly stampedes mirroring risks of increasing overall population densities, especially in low- and middle-income countries (de Almeida and von Schreeb, 2019), the number of reports may in reality reflect greater sharing of information via mass media. Numerous other events before the 1990s, particularly in less developed countries, may have resulted in sizeable stampedes that were unreported. In general, injuries are estimated or are not recorded, whereas direct deaths (not including deaths following injuries) are more precisely reported and readily obtained (Ngai et al., 2009; Still, 2019). Often stampede and crushing events occur due to the systematic failure of organisations to provide a safe environment for places of public assembly (Still, 2019).

Between 1980 and 2007, the Ngai method identified 215 stampede events worldwide, and 350 events between 1980 and 2012, resulting in 7069 deaths and 14,078 injuries (Hsieh et al., 2009) increasing to 10,243 deaths and 22,445 injuries between 1980 and 2012 (Ngai et al., 2009). Women, children, and older people were reportedly more affected because they were less able to defend themselves from external weight pressure (de Almeida & Von Schreeb, 2019).

Multi-hazard Context: Rapid-onset hazards (Meteorological and Hydrological, Extraterrestrial, Geohazard, Environmental, Chemical, Technological, or Societal) occurring during a mass gathering may lead to a stampede. Stampedes may trigger other hazards (Environmental, Chemical, Technological, or Societal).

Monitoring: No Information Available.

Risk Management: Both organised and unplanned mass-gatherings strain the planning and response resources of the community, state or nation hosting the event. A safe and healthy mass gathering requires early multi-sectoral preparation involving event organisers, health emergency managers, public health authority representatives, local hospital emergency departments, first-aid personnel and other sectoral partners, including police and emergency services (WHO & PHE, 2017). Findings from the Seoul Halloween crushing emphasise the importance of proactive measures including proper police presence and response, managing the flow of people, and effective communication.

A risk assessment is an essential part of planning for any event. This informs the selection and implementation of risk reduction measures, response planning, and capacity development for health operations, including mass casualty management; on-site trauma care and local hospitals; disease surveillance and outbreak response; environmental health and food safety; public information and health promotion; leadership, coordination and communication; and emergency preparedness and response (WHO and PHE, 2017).

Preliminary – Corrections Pending

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Coordination agency or organisation

World Health Organization.

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SO0303 / SOCIETAL / Behavioural

Suicide Cluster

Definition

The term 'suicide cluster' describes a situation in which more suicides than expected occur in terms of time, place, or both (PHE, 2019). Two types of suicide clusters can be distinguished (Joiner, 1999): clusters where suicides occur during a restricted time period and are related to actual or fictional media-related phenomena, and space-time clusters (or point clusters), where an unusually high number of suicides occur in a small geographical area, or institution, and over a relatively brief period of time (adapted from Joiner, 1999 and PHE, 2019).

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Annotations

Synonyms

Suicide pact, Group suicide, Suicide contagion, Suicide imitation, Mass suicide.

Additional scientific description

Adolescents and young adults are most at risk of being part of a suicide time cluster, as vulnerable and alienated from other adolescents in the community (Haw et al., 2013). Contagion is the most relevant method of cluster formation, via word of mouth or media, and various mechanisms of contagion have been suggested, including modelling, suggestion, imitation, and priming. Brantez and Houle (2024) note that while social integration is negatively associated with individual suicide rates, social integration is positively associated with the emergence of suicide clusters. Suicide clusters disrupt the affected communities because of the concentration of an unusual number of deaths, as well as of concerns of potential additional suicides (Haw et al., 2013).

The term mass suicide - a space-time cluster - can be used to describe situations in which a particular population or social group has reacted to (real or perceived) oppression or exploitation by another group or agent. The act of mass suicide transforms the psychology of a disaster from one in which - most commonly - a passive role is played into one constructed actively (Mancinelli et al., 2002). Mass suicides can therefore be classified as either self-induced (perceived) – the motivation is related to a distorted evaluation of reality, without there being either an intolerable situation or a real risk -; or hetero-induced (real), typical of defeated and colonised populations that are forced to escape from a reality in which human dignity is not acknowledged and typical of communities with a well-defined historical and cultural identity (Mancinelli et al., 2002).

Documented examples of mass suicide events exist, and these range from 113 BC to more recent events, and have occurred in most regions of the world (Mancinelli et al., 2002). Mass suicides prompted by a perceived threat are often religious in

nature and can be triggered by a charismatic leader (Dein and Littlewood, 2000). Examples include the Peoples Temple in 1978 where 909 Americans died in a group led by Jim Jones in Guyana, and Adam House in Bangladesh where nine members of the same family threw themselves in front of a train in 2007 (Selum, 2010). Mass suicides prompted by real threats most often occur during wartime, particularly among defeated or invaded populations (Goeschel, 2006).

There are reported to be substantial differences in the pattern of suicide methods internationally (Ajdacic-Gross et al., 2008). It is difficult to ascertain the extent to which clusters contribute to overall suicide rates. Up to 2% of suicides in young people may occur in clusters i.e., close together in time and space (Jones et al., 2013). Approximately 5% of all suicides in New Zealand appeared to occur in point clusters and 2.4% of suicides in Australia. The estimation of such figures is approximate. It is not known how many suicides occur in mass clusters because accurate identification of those affected may be impossible as they tend to be geographically remote; sometimes linked deaths occur in different countries (PHE, 2019).

The World Health Organization reported that every year an estimated 727,000 suicide deaths occur worldwide (WHO, 2025). This indicates an annual global age-standardised suicide rate of 9.0 per 100,000 population. For every suicide, there are many more people who attempt suicide every year. Suicide is the third leading cause of death among 15-29-year-olds (WHO, 2025). In fact, close to three quarters (73%) of global suicides occurred in low- and middle-income countries in 2021 (WHO, 2025).

Metrics and numeric limits

WHO reports that every year an estimated 727,000 suicide deaths occur worldwide (WHO, 2025).

Key relevant UN convention / multilateral treaty

Not relevant.

Examples of hazard drivers, impacts and risk management

Hazard Drivers: The main drivers of mass suicides are associated with political and religious motivation and mental health (Mancinelli et al., 2002); as well as psychological mechanisms of contagion (Haw et al., 2013) and having access to the means of committing suicide. For example, Niederkrotenthaler et al. (2020) showed that reporting of deaths of celebrities by suicide appears to increase the number of suicides by 8-18% in the subsequent 1-2 months, and information on the method of suicide was associated with an increase of 18-44% in the risk of suicide by the same method. Studies on the effects of media items covering novel suicide methods have been useful in understanding the interplay between media and suicide methods, for example, charcoal burning in parts of Asia (Lee et al., 2014).

Mental disorders and the harmful use of alcohol contribute to many suicides around the world (WHO, 2025). Cultural variability in suicide risk is also apparent, with culture having roles both in increasing risk and in protection from suicidal behaviour (WHO, 2014). In the past half-century, many countries have decriminalised suicide, making it easier for those with suicidal behaviours to seek help (WHO, 2023). Public Health England recommends the development of a Suicide Cluster Response Plan (PHE, 2019). WHO recommends to Member States in the Mental Health Action Plan to lead and coordinate a multisectoral strategy that combines universal and targeted interventions for: promoting mental health and preventing mental disorders; reducing stigmatization, discrimination and human rights violations; and which is responsive to specific vulnerable groups across the lifespan and integrated within the national mental health and health promotion strategies (WHO, 2018).

Haw et al. (2013) reported in their review of the literature for suicide clusters that the following as being significant for suicide risk factors:

- male gender, adolescent or young adult,
- a family history of suicide, a family history of alcohol abuse,
- personal history of unstable family or home life, poor educational experience, employment problems, loss of traditional ways, victim or witness of abuse, experienced violence, violence toward others, history of arrest/antisocial behaviour, experienced death of close friend or relative
- psychiatric history with a history of self-harm or threats of self-harm/suicide, previous psychiatric hospitalization, drug and/or alcohol abuse depression; and life events and psychological factors such as recent relationship breakup or threat of breakup, social isolation, inability to express feelings, easily emotionally hurt or offended, poor self-esteem and direct involvement with another cluster victim (Haw et al., 2013).

Impacts: As an example, Jones et al. (2013) reported on a possible suicide cluster: in early 2008 unprecedented attention was given by national and international news media to a suspected suicide cluster among young people living in Bridgend, Wales. Analysis of all deaths by suicide, undetermined intent, accidental poisoning and accidental hanging (possible

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suicides) identified a temporo-spatial cluster (p = 0.029) involving 10 deaths amongst 15-34-year-olds centred on the County Borough of Bridgend for the period 27 December 2007 to 19 February 2008. This cluster was smaller, shorter in duration, and predominantly later than the phenomenon that was reported in national and international print media (Jones et al., 2013).

Another cluster was reviewed by Hill et al. (2023). They identified coroner-confirmed cases of suicide (ICD-10 codes X60-X84) in young people (aged 10-25 years) and adults (aged 26 and above) who died in Australia between 1 January 2016 and 31 December 2020 using the National Coronial Information System (NCIS). They found that between 1 January 2016 and 31 December 2020, eight hotspots (clusters of high relative risk) were detected across six Australian states and territories. These hotspot communities comprised 228 young people, accounting for 12% of youth suicides during the study period. The identification of geographic hotspots of suicide has important implications for suicide prevention, including directing resources to areas where the need is greatest. Findings from this study highlight both the risk and protective role that the mental health workforce supply may play in the spatial distribution of youth suicide clusters. These findings have important implications for the provision of postvention support in the aftermath of a suicide and for the prevention of suicide clusters. Improving access to mental health services can be achieved by increasing the capacity of the mental health workforce, and through the introduction of novel telehealth and digital interventions (Hill et al., 2023).

Multi-hazard Context: Mass suicide may be triggered by the occurrence of other hazards, in particular in the case of other societal hazards, such as those involving violence, conflict or financial shock.

Monitoring: Despite evidence that many deaths are preventable, suicide is often a low priority for governments and policymakers (WHO, 2014). Notwithstanding, many suicides happen without forewarning and, in such circumstances, easy access to a means of suicide – such as pesticides, or hanging – can make the difference as to whether a person lives or dies (WHO, 2014).

Risk Management: Media, and social media, can play a role in suicide prevention in vulnerable groups during a cluster (PHE, 2019), protecting vulnerable or impressionable individuals, because appropriately responding to single suicides can reduce the risk of a spread of suicidal behaviour (PHE, 2019). To that end, social media may adopt content moderation practices to filter messages that may induce suicide.

Trinh et al. (2024) have developed CDC guidance that is designed to support and assist communities in the assessment and investigation of suspected suicide clusters that can ultimately guide public health action (e.g., community response) to prevent suicide. Investigating a suspected cluster requires substantial time and resources for the lead agency and community. Ideally, the committee and liaison are prepared to receive concerns, engage key partners, and assess and investigate suspected clusters. This CDC guidance provides direction for a carefully planned and implemented process. Having an established approach can help an agency and community prepare the infrastructure and resources to readily act when suicide clusters are suspected or confirmed. Although suicide clusters comprise a small proportion of suicides, a suicide cluster or the perception of a suicide cluster can greatly affect communities (Trinh et al., 2024).

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Coordination agency or organisation

World Health Organization.

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SO0401 / SOCIETAL / Economic

Financial shock

Definition

A financial shock is an unexpected disturbance which originates from the financial sector and has a significant effect on an economy (e.g. national, regional, or global). The term is largely used to refer to events which have negative impacts (ECB, 2013).

Reference

ECB, 2013. Financial Shocks and the Macroeconomy: Heterogeneity and Non-Linearities. European Central Bank (ECB), Occasional Paper Series No. 143. www.esm.europa.eu/sites/default/files/financialshocksandthemacroeconomy.pdf Accessed 20 March 2025.

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Annotations

Synonyms

Financial crisis, Bank run, Banking crisis, Currency crisis, Debt crisis, Liquidity crisis.

Additional scientific description

The term 'financial shock' generally refers to a disruptive event in the financial system, which manifests in the sudden re-pricing of assets (often in combination with a severe deterioration of economic conditions). Financial shocks are difficult to predict but tend to be more likely when borrowers are vulnerable, such as when they have taken on excessive risk relative to their repayment capacity (e.g. highly leveraged firms that have both uncertain future profits and low liquidity) (Peersman, 2015).

Financial shocks may be triggered by different factors inside and outside the financial system. They are often amplified by adverse macro-financial feedback effects, such as when a deterioration in economic conditions weakens the solvency of financial institutions and markets, which in turn results in tighter financial conditions for firms and households (Ong & Jobst, 2013). A significant economic slowdown could lead to rising business insolvencies, higher unemployment, and constrained public investment. They can morph into financial crises if a sharp decline in asset prices causes consumers and businesses to default on their loans, and financial institutions become unable to access liquidity – either in terms of cash or assets which are easily convertible into cash (Moretti et al., 2020).

For example, the collapse of the USA sub-prime mortgage market, prior to the 2007-2009 Global Financial Crisis, was largely driven by excessive leverage of borrowers, an overheated housing market, and insufficient transparency when banks re-packed and combined mortgage loans into new financial instruments, through what is referred to as 'securitization' (Jobst, 2008). Recent currency and/or sovereign debt crises also illustrate that unsustainable external imbalances, such as a deteriorating current account (which reflects cross-border economic activities) and rising foreign currency borrowing by public or private sector organizations (if suddenly unwound), can amplify and/or cause fragilities in the financial system. Examples include the cases of the 1997 Asian financial crisis and the 2007-2009 Global Financial Crisis (Claessens et al., 2014).

Metrics and numeric limits

Measures linked to financial shocks typically focus on aspects of financial stability, due to the inherent difficulty in predicting the occurrence of financial shocks (IMF, 2020a). Examples of these measures include:

Financial sector: financial soundness indicators (solvency, liquidity, asset quality) of banks and non-bank financial institutions (insurance companies, investment funds, and other asset managers), default risk (via credit ratings or credit default swap spreads).

Financial markets: equity prices, corporate bond spreads (as measure of default risk), market liquidity/volatility, and house prices (indicate bubbles/crashes).

Other sectors: measures of corporate financial risk (e.g. corporate debt), households (e.g. household debt), and governments (e.g. public debt), as well as real economic activity (e.g. GDP growth, interest rates, inflation) and external ratios (e.g. balance of payments, exchange rates).

Key relevant UN convention / multilateral treaty

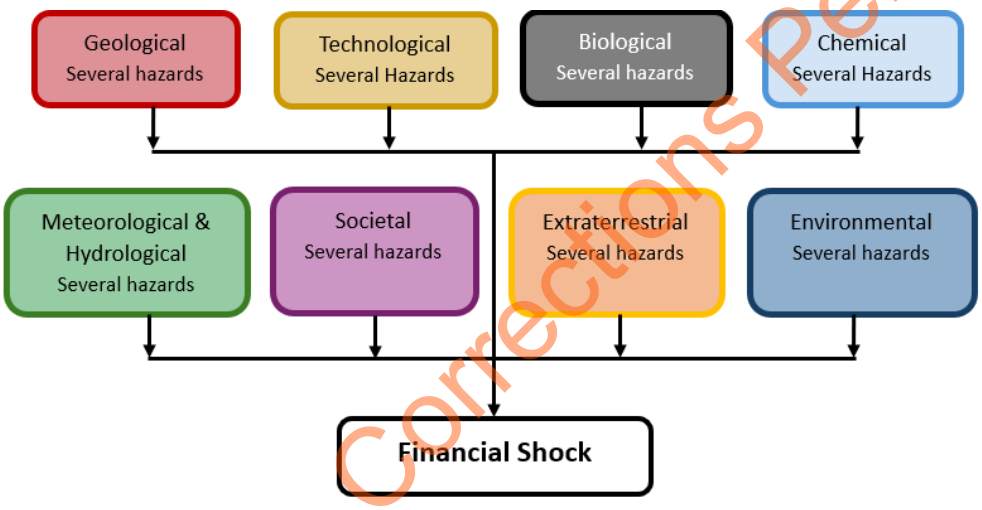
Articles of Agreement of the International Monetary Fund (IMF, 2020b); and Basel III: A Global Regulatory Framework for More Resilient Banks and Banking Systems (Bank for International Settlements, 2020).

Examples of hazard drivers, impacts, and risk management

Hazard Drivers: Several hazards may result in financial shocks.

Impacts: Financial Shocks may result in supply chain failure and civil unrest.

Multi-hazard Context: The figure below summarises common interactions between financial shock and other hazards. This information should be used with caution and not be solely relied upon in Disaster Risk Management, particularly as some interactions may not have been included. Note that hazardous events occurring together or locally in space or time may not necessarily cause, amplify, or be otherwise related to each other. Specific examples of multi-hazard context can be found in the 'Hazard drivers' and 'Impacts' sections above.



Monitoring: Central banks, commercial financial institutions, and international organizations, such as the International Monetary Fund, Financial Stability Board, and Bank for International Settlements, monitor and produce data on the risk of financial shocks. This involves specific and system-wide supervision and surveillance of financial institutions, including measures such as asset prices, the credit gap (e.g. measures of excessive lending), and the output gap (e.g. measures of economic overheating or slowdown) (Chen & Svirydzenka, 2021). Early warning systems can pick up signals of potential financial shocks several months and even years prior to the onset of a financial shock, based on aggregated information (Chen & Svirydzenka, 2021). This information is then shared via public reporting and direct communications among financial institutions and regulators.

Risk Management: The health and functioning of a country's financial sector have far-reaching implications for its own and other economies. Prudential regulators and supervisors play a central role in safeguarding the capacity of the financial system – its intermediaries, markets and infrastructures – to provide deposit, credit, and other financial services to households, firms, and governments (OECD, 2010).

Designing policies that align private incentives with the public interest to facilitate market discipline and limit excessive risk-taking is challenging. In some cases, a financial institution and/or market might be considered Too-Big-To-Fail (TBTF), because their insolvency and failure could cause massive disruptions to the functioning of the financial system, resulting in a significant tightening of financial conditions and a contraction of economic activity. This situation creates an expectation that they would be bailed out by the government, via direct financial support measures, during times of stress. Safety nets, such as deposit insurance (guaranteeing bank depositors access to their money even if a bank fails), play an important role as shock absorbers, helping to maintain the functioning of the financial system during times of stress.

Early warning systems for financial shocks help policymakers reduce the risk of rapid falls in market confidence and institutional solvency which can lead to widespread economic hardship, loss of jobs, and social instability. These systems work through real-time supervision and periodic assessments. At the national level, regulated financial institutions are subject to both microprudential and macroprudential oversight:

- Microprudential supervision focuses on the safety and soundness of individual financial institutions, such as banks, insurance companies, and investment funds. Supervisors complete regular on- and off-site inspections and reviews to ensure that these financial institutions are well-managed and have enough capital to absorb the impact of adverse shocks (such as a recession).

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- Macroprudential surveillance elevates this concept of financial supervision to a system-wide perspective, by focusing on common vulnerabilities across all or several institutions. Macroprudential measures to mitigate risk, such as additional capital requirements, are not specific to individual firms but apply uniformly across all relevant institutions.

International institutions facilitate cross-border coordination across supervisors and regulators through agreements on common standards and peer reviews (e.g. Bank for International Settlements, Financial Stability Board) while others focus on multilateral surveillance and direct engagement with countries, often via capacity building and technical assistance (e.g. International Monetary Fund, World Bank) (IMF, 2020a; World Bank, 2020). At the international level, these activities include:

- The Financial Sector Assessment Program (FSAP) is a comprehensive and in-depth analysis of a country's financial sector. FSAP assessments are the joint responsibility of the IMF and World Bank in "developing economies and emerging markets", and of the International Monetary Fund alone in "advanced economies" (IMF, 2019).
- The Early Warning Exercise (EWE) is a semiannual assessment by the IMF and the Financial Stability Board (FSB) of low-probability, high-impact risks –also known as tail risks– to the global economy. It was created in 2008 when the G20 asked both institutions to work jointly on an early warning exercise to help policymakers spot tail risks and vulnerabilities that could lead to further systemic shocks (IMF, 2023).

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Coordinating agency or organisation

International Monetary Fund.

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