Words into Action Guidelines:
National Disaster Risk Assessment
Hazard Specific Risk Assessment

5. Biological Hazards Risk Assessment

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Biological hazards are a major source of risk that may result in emergencies and disasters. They cause significant loss of life, affect many thousands of people, have the potential for major economic losses through loss of livestock and crops, and may also cause damage and loss to the natural heritage, including to endangered fauna and flora.

The management of risks due to biological hazards is a national and community priority. It has been recognized as part of the Sendai Framework, and is globally addressed under the International Health Regulations (IHR).

Biological hazards – what are they?

Biological hazards are of organic origin or conveyed by biological vectors, including pathogenic microorganisms, toxins and bioactive substances. Examples are bacteria, viruses or parasites, as well as venomous wildlife and insects, poisonous plants, and mosquitoes carrying disease-causing agents [1].[1] These hazards are usually the result of a natural occurrence, but can also result from deliberate or accidental release.

Biological hazards also pose a risk to animals, including livestock, and to plants. However, we are focusing here on human health. The consequences of a biological hazardous event may include severe economic and environmental losses. Some examples of recent large outbreaks,[2] epidemics[3] or pandemics[4] due to biological hazards either on their own or following a disaster are:

- The Ebola Virus Disease outbreak in West Africa in 2013-2016, the largest epidemic of its kind to date in the populations of Guinea, Liberia, and Sierra Leone.
- The ongoing outbreak of Zika virus infection in the Americas and the Pacific region, associated with congenital and other neurological disorders.
- Significant increase in diarrheal disease incidences following recurrent floods in most African countries or significant increase following the 2004 tsunami in Indonesia and Thailand [2].
- Outbreaks of yellow fever in Angola, the Democratic Republic of Congo and Uganda in 2016.

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1 http://preventionweb.net/go/488

2 A disease outbreak is the occurrence of cases of disease in excess of what would normally be expected in a defined community, geographical area or season. An outbreak may occur in a restricted geographical area, or may extend over several countries. It may last for a few days or weeks, or for several years. A single case of a communicable disease long absent from a population, or caused by an agent (e.g. bacterium or virus) not previously recognized in that community or area, or the emergence of a previously unknown disease, may also constitute an outbreak and should be reported and investigated. www.who.int/topics/disease_outbreaks/en/

3 Epidemic: The occurrence in a community or region of cases of an illness, specific health-related behaviour, or other health-related events clearly in excess of normal expectancy. http://www.who.int/hac/about/definitions/en/

4 A pandemic is the worldwide spread of a new disease. www.who.int/csr/disease/swineflu/frequently_asked_questions/pandemic/en/

- Outbreaks of Middle East Respiratory Syndrome – Coronavirus (MERS CoV), an emerging disease identified in 2012.

Assessing the risk of biological hazards can be challenging owing to their unique characteristics:

- **Agent diversity.** Biological hazards range from microorganisms such as bacteria or viruses, to toxins to insect infestations. They can be transmitted to humans from the environment, from animals, from plants, and from other humans.
- **Routes of transmission.** These include airborne transmission, ingestion, absorption (through the skin, eyes, mucous membranes, wounds), animal vectors (e.g. mosquitos or ticks), and bodily fluids (e.g. blood, mother-to-child transmission, sexual transmission).
- **Pathogenicity and virulence.** Some biological hazards can cause severe disease in extremely low concentrations and can multiply quickly once within its host. For example, 1-10 aerosolized organisms of Lassa virus or Ebola are sufficient to cause severe disease in humans.
- **Hazard identification.** As microbes are not visible to the naked eye, they are often not easy to identify on the basis of epidemiological information derived from clinical signs and symptoms. They therefore require specific diagnosis techniques, including polymerase chain reaction (PCR), to amplify a single copy or a few copies of a piece of DNA, microbial cultures, whole genome sequencing.
- **Endemic diseases with potential for epidemic transmission.** Unlike some other hazards (e.g. earthquakes or floods), biological hazards can be present in the community (i.e. they are endemic) and usually pose low risk when the population is largely immune. The risk may change when crises or emergencies arise, exacerbating the conditions favourable for disease transmission, or when people migrate from disease-free areas to endemic regions typically lacking immunity, making them susceptible to infection and transmission of the disease resulting in cases in excess of normal expectancy. Biological hazards, which are not endemic also pose a risk when they are introduced to a new host community with no immunity.
- **Sensitivity to climate, environmental or land use changes.** Biological hazards – particularly zoonoses5 and vector-transmitted diseases such as malaria, dengue, Zika and Ebola – may increase in incidence, lethality or change geographic distribution or seasonal patterns directly due to climate and weather sensitivity, environmental or land-use changes, or mediated through changes in ecosystems resulting from human activities, thus

5 Zoonoses are diseases and infections that are naturally transmitted between animals and humans. A zoonotic agent may be a bacterium, a virus, a fungus or other communicable disease agent. www.who.int/neglected_diseases/diseases/zoonoses/en/

changing human exposures and susceptibility to these hazards.
An estimated 75 per cent of emerging infectious diseases of humans that have evolved from exposure to zoonotic pathogens [3] warrant risk assessments for health threats at the interface between animal, human and ecosystems.

Assessing the risk of biological hazards

Approaches in assessing the risks of biological hazards differ according to the purpose of the assessment:

- **Strategic Risk Assessmen**t is used for risk management planning with a focus on prevention and preparedness measures, capacity development and medium- to longer-term risk monitoring and evaluation.
- **Rapid Risk Assessment** is used to determine the level of risk associated with detected events and to define response interventions accordingly.
- **Post-event assessment** is used for recovery planning, updating and strengthening the overall risk management system.

Pre-event: Strategic Risk Assessments

Strategic Risk Assessments are used for risk management planning with a focus on prevention and preparedness and capacity development before events occur. They can be used for medium- to longer-term risk monitoring and evaluation, which tracks changes in risk over time. They catalyse targeted action to reduce the level of risk and consequences for health based on assessment of the hazard, exposure, vulnerabilities and capacities.

In relation to addressing the risk of biological hazards, the term vulnerability refers to the risk factors that exist in exposed populations, such as the burden of endemic diseases, living conditions (e.g. overcrowding) and environment (e.g. favourable environment for the growing of the pathogen). This is in addition to factors that are addressed in risk assessments for other hazards, such as demographics (e.g. age or gender), the availability of health services to those populations and the degree of resilience of the health systems.

Some examples of strategic risk assessment methods for biological hazards are outlined below.

A quantitative microbiological risk assessment (QMRA) is an example of a strategic risk assessment for prevention and mitigation of risks. The hazard identification includes identifying the characteristics of the pathogen/microbial agent (i.e. case fatality ratios, transmission routes, incubation times…) and the human diseases associated with the specific microorganism. This information can be found in the literature and it could be also helpful to search for similar outbreaks as references.

The exposure assessment of the QMRA measures the dose of the pathogen that an individual ingests, inhales or comes in contact with. It also requires data on the concentration of the pathogen in the source, route of transmission and timing of the exposure.

For this purpose, the QMRA Wiki [4] is a community portal with evolving knowledge repository for the QMRA. In addition, some other available and free access QMRA tools are E3 Geoportal (European Environment and Epidemiology Network) QMRA for Food and Waterborne Diseases [5] and the QMRA spot for drinking water [6].

To prepare for an event involving biological hazards, different approaches to ranking risks could be used, including multi-criteria decision analysis (MCDA) and burden of diseases. These approaches allow for better risk prioritization and planning of public health preparedness.

The World Health Organization (WHO) STAR approach to strategic risk assessment enables countries to incorporate an evidence-based approach to strategic risk assessments. The approach is designed to: engage multisectoral stakeholders around a risk assessment developed for risks affecting public health; provide a systematic, transparent and evidence-based approach to identify, rank and classify priority hazards by level of risk; and for each hazard, to define the level of national preparedness and readiness required to mitigate its risk. The tool is available from WHO on request.

Multi-Criteria Decision Analysis (MCDA) is a stochastic/randomized approach in which several criteria with their levels are identified according to the outcome of interest. Criteria may include information on epidemiological, economic and perception data of the diseases. The criteria can have equal or different weights depending on their relative importance for the outcome. These data can be collected from literature, databases from the official sources, prevalence studies or studies in the field, and from expert consultations. An example is a tool developed by the European Centre for Disease Prevention and Control (ECDC) for ranking infectious diseases to support preparedness planning in the European Union/European Economic Area countries with two versions: a qualitative and less detailed version and a semi-quantitative and more detailed version. Both versions are developed in a flexible way, allowing the users to modify the weighting factors to their own countries. MCDA has also been applied in the WHO Research and Development Blueprint for action to prevent epidemics, which utilizes a combination of the Delphi technique, questionnaires and multi-criteria decision analysis to review and update the Blueprint's priority list of diseases [7].

The Global Burden of Disease (GBD) estimates provide comprehensive and comparable assessment of mortality and loss of health due to diseases, injuries and risk factors, examining trends from 1990 to the present and making comparisons across populations. The estimates provides an

understanding of the changing health challenges facing people across the world [8]. GBD research incorporates both the prevalence of a given disease or risk factor and the relative harm it causes. The tools allow decision makers to compare the effects of different diseases and use that information for policymaking. The flexible design of the GBD machinery allows for regular updates as new data and epidemiological studies are made available. In that way, the tools can be used at the global, national and local levels to understand health trends over time [9-10].

The Burden of Communicable Disease in Europe toolkit [11] estimates the burden for 32 communicable diseases and six healthcare-associated infections, applying composite health measures – disability-adjusted life years (DALYs) – to summarize the overall burden in one single metric and compare the relative burden of each communicable disease.

Detection and response: Rapid Risk Assessment

When an event occurs, and in order to inform early warning and response measures, the level of risk posed by the event itself is assessed on a continuous basis through rapid risk assessments [12,13]. The key parameters to take into account in the risk assessment of communicable diseases are the probability (likelihood of transmission in the population) and the impact (severity of the disease), as well as the context in which the disease occurs.

The initial rapid risk assessment must be generated within a short time period when information is often limited and circumstances can evolve rapidly. The assessment should be undertaken in the initial stages of an event or of an incident being reported and verified, and should ideally be produced within 24 to 48 hours. The level of risk should be re-assessed based on evolving information on the event and disease pattern. Risk assessments will help determine whether a response is indicated, the urgency and magnitude of the response, the design and selection of critical control measures; and they will inform the wider implications and further management of the incident.

In the light of time constraints, the assessment generally relies on published research evidence, on specialist expert knowledge, and on experience gathered through previous similar events. Some sources for identifying outbreaks and obtaining disease information are listed in the WHO Rapid Risk Assessment manual [12], and in appendix 3 of the ECDC operational guidance on rapid risk assessment methodology [13]. The principles of transparency, explicitness and reproducibility strictly apply to a rapid risk assessment. In addition, uncertainties must be identified, clearly documented and communicated.

It is important for the public health team in charge of risk assessment to have the following available:

- A repository of events that occurred in the past
- Evidence-based protocols and guidance ready to use for responding to incidents
- Protocols for identifying sources of key information for rapid risk assessment
- Strategies for rapid literature searches
- Lists of experts who can be consulted.

Post-event or post-disaster assessments and after-action reviews

As health needs might not be immediately apparent, it is important to assess the risk of biological hazards after natural or human-induced disasters. Damage to health-care facilities and diagnostic and treatment equipment and interruption of services such as power cuts can have long-reaching consequences affecting the proper functioning of health facilities, including the preservation of the vaccine cold chain.

The availability of safe water, sanitation facilities and hygiene conditions before, during and after a disaster can greatly determine the impact on a community's health and can result in water-related communicable diseases or vector-borne diseases. Other diseases such as tetanus are also associated with natural hazardous events, where contaminated wounds – particularly in populations where vaccination coverage levels are low – are associated with illness and death from tetanus.

Population displacement is also associated with outbreaks of diseases associated with overcrowding. Disasters can also exacerbate non-communicable diseases and mental health needs and increase demands for sexual and reproductive health services.

Post-disaster assessments also inform the implementation of recovery, reconstruction, rehabilitation and restoration of services and other health-related activities, including plans for ongoing and latent risks to population health, and the application of "build back better" principle to ensure that future risks of emergencies and disasters are reduced.

Health impact assessments include identifying existing and latent risks to population health. A rapid risk assessment of these potential risks to human health, and reports on the acute event and syndromic surveillance indicators are needed. As an example of how to implement a syndromic surveillance in a specific population, ECDC launched a handbook and supporting tool for implementing syndromic surveillance in migrant centres and other refugee settings [14].

Post-event reviews (e.g. after-action reviews (AAR) or critical incident reviews) are qualitative reviews of actions at any level, usually focused on the response to an event, as a means of identifying best practices and lessons learned [15]. An AAR seeks to identify what worked well and how these practices can be institutionalized and shared with stakeholders; and what did not work and requires corrective action. AARs can be used as an evaluation of the real response capacities and processes in place.

AARs following epidemics and pandemics usually include evaluations of the capacity of the organization and health and multisectoral systems to deal with the risk, the availability and the enforcement of legal instruments, and issues of leadership and coordination. For example, several reviews have been conducted following the Ebola outbreak in West Africa 2013-2016 [16-18]. A typical review looks at the scale of the epidemic, origins of human infection, spread patterns of the infection, the effects of the interventions taken in both timing and magnitude, the declaration of the end of the epidemic, and finally lessons learned for future preparedness and response.

Risk assessment and use in national DRR measures

Risk assessment will inform policymaking of the management of the risks, including biological hazards, by answering the following important questions:

- Who is at risk? Who is more exposed or in vulnerable situations? What is the level of exposure and the rate of assumed risky behaviours?
- What are the routes of transmissions within and between communities?
- What is the level, severity and scale of the risks? What are the established thresholds that apply to this particular pathogen based on past and present disease incidence?
- What is the risk of international spread that warrants reporting the event under the International Health Regulations (2005) and which may lead to a declaration by WHO of a Public Health Emergency of International Concern?
- What are the effective treatment and control measures available to use to contain and stop the risk?
- What are the environmental and ecological factors or drivers affecting the risk? What is the likelihood and impact of emerging or evolving health threats? How can they be mitigated?
- What are the contextual factors to take into account when managing the risks? These include public perception and behaviour, media interest and political and economic issues.

Policy makers and DRR practitioners use this information to trigger actions that reduce risk of biological hazards i.e. effective and timely prevention, preparedness and response actions, including measures to reduce exposure of groups at increased risk of infection due to biological hazards, contain the spread of the risk, and eventually stopping it.

Measures include protective equipment, behaviour-change practices by raising awareness and education of the public through appropriate communication channels, and effective treatment and/or vaccine if and when available.

Risk information is also used to inform preparedness and contingency planning at various levels and capacity-development measures for health workers to match the full risk profile of the community, including for biological hazards.

Risk assessment information provides the foundation for investment in measures to reduce the risk. For example, identification and mapping of hazardous areas inform the decisions for building critical infrastructure such as water, sanitation and health systems and services to manage the risks of biological hazards as well as other types of emergencies. They also provide the foundation for developing financial applications to manage or transfer the risk.

Impact modelling and rapid risk assessment inform early and rapid estimates of impacts on the populations, on services in health and other sectors, and provide critical information for recovery and rehabilitation reconstruction when needed.

Case studies of a country good practice

Case study: Rapid Risk Assessment of a severe respiratory disease

Event: A cluster of 22 cases of severe respiratory disease with seven deaths in country X were admitted to hospital over the past 17 days. The event is occurring 8 km from the border and cases have been reported from three villages by a local health-care worker. The area is the poorest in the country and health infrastructure is limited.

Many of the health-care facilities charge a consultation fee and consequently the local population self-medicates during mild illness. There are also strong beliefs that "strange diseases" are caused by sorcery.

Risk question: What is the likelihood of further spread of severe cases of respiratory disease and what would be the consequences (type and magnitude) to public health if this were to occur?

Information used to assess the likelihood of further spread:

- Cases are still being reported 17 days after the first known cases were detected
- The specific hazard and mode(s) of transmission have not been identified
- It is also likely that some cases are not being detected (e.g. mild cases are less likely to seek care from health services and are therefore not included in the official reports).

Therefore, if nothing is done, it is highly likely that further cases will occur.

Information used to assess the consequences of further spread:

- The disease has a high case fatality ratio (even when underreporting is taken into account)
- The health-care system is poor and the ability to treat the cases is already limited; new

admissions will further stress acute care services and lead to worse clinical outcomes for hospitalized patients

- Negative economic and social impact of the cases and deaths in the affected communities
- Potential for unrest in communities because of cultural belief that sorcery is causing the deaths
- The event is occurring in a border area and could affect the neighbouring country.

Therefore, if further cases occur, the consequences will be severe.

Using the risk matrix to combine the estimates of likelihood and consequences leads to an estimate of the overall risk. In this case, the overall level of risk is high. The confidence in the risk assessment is low to medium.

Although the report is from a local health-care worker, the information is limited and it is not clear if that person has examined the suspect cases or is merely reporting a rumour.

Source: http://apps.who.int/iris/bitstream/10665/70810/1/WHO_HSE_GAR_ARO_2012.1_eng.pdf

Case study – Collaboration between the Chief Epidemiologist and Civil Protection in Iceland on risk assessment

An island country located in the North Atlantic Ocean, Iceland has a population of some 330,000 inhabitants and an area of 103,000 km2, making it one of the most sparsely populated countries in Europe. Over two thirds of the population live in the southwest part of the country, which makes up the Reykjavik area, while the rest are scattered along the coastal area.

Iceland's Chief Epidemiologist and the Civil Protection service of the National Commissioner of Police are responsible for the national preparedness planning for communicable diseases, as well as chemical, biological and radio-nuclear hazards and events where the source is unknown. Additionally, the Chief Epidemiologist, in cooperation with the Civil Protection service, is responsible for the national risk assessment, risk reduction and response management for these types of events.

In times of crisis, the risk assessment is performed in cooperation with responders and scientists at formal meetings at the National Coordination Centre. Meetings are scheduled as often as needed and a press release issued after each meeting. The objective of the meetings is to share information, assess the risk and decide whether preparedness plans should be activated.

The preparedness plans in Iceland are all-hazard plans and involve the following sectors [19]: primary health care and hospitals, ambulance services, distributors of medicines, Icelandic Medicine Agency, Icelandic Food and Veterinary Authority, food suppliers and distributors, the Farmers Association of Iceland, Icelandic Transport Association, Icelandic Tourist Board, the financial sector, Icelandic Environmental Agency, Icelandic federation of energy and utility companies, Icelandic road and coastal administration, prisons, Red Cross and rescue services, Icelandic National Broadcasting Service and the Evangelical Lutheran Church of Iceland.

The main health hazards in Iceland result from natural hazards such as volcanoes, earthquakes, avalanches and severe weather. Hazards from volcanoes have been a great concern in Iceland for years. These hazards can result from heavy ash fall and various gases being emitted from eruptions, the main one being sulphur dioxide (SO2).

The evaluation of possible health effects involves various agencies but the final risk assessment, risk mitigation and communication to the public is the responsibility of the Chief Epidemiologist and Civil Protection. Several Icelandic studies have been published that describe the health effects of volcanic eruptions in Iceland. These studies are invaluable in the making of preparedness plans for hazards due to volcanic activities in Iceland as well as for carrying out risk assessment and risk reduction.

Resources for further information

Open-source modelling tools available

- E3 Geoportal (E3 tools): Vibrio, West Nile, E3 map viewer (Dengue, Chikungunya, mosquitoes), Quantitative Microbial Risk Assessment for food and waterborne diseases (QMRA).
- ECDC Legionnaires' disease GIS tool. "It allows field epidemiologists to quickly plot cases and potential outbreak sources, and to make a basic spatial analysis to support the source identification".
- European Up–Front Risk Assessment Tool (EUFRAT). "Quantification of the risk of infection transmission by blood transfusion in an outbreak-affected region, or the risk from a stream of donors who have visited such a region".
- Global Burden of Disease Data Tool. "[…]tool to quantify health loss from hundreds of diseases, injuries, and risk factors, so that health systems can be improved and disparities can be eliminated".
- Burden of Communicable Disease in Europe toolkit. "[…] stand-alone software application which allows calculation of disability-adjusted life years (DALYs) for a selection of 32 communicable diseases and six healthcare-associated infections".
- Joint External Evaluation Tool. "[…] is intended to assess country capacity to prevent, detect, and rapidly respond to public health threats independently of whether they are naturally occurring, deliberate, or accidental".

List of entities to consult for more guidance on health risk assessment

  - Departments of health at national, provincial and municipality levels
- Health emergency management sections
- Civil protection agencies
- Food safety agencies
- Vector control agencies
- Water and sanitations agencies
- Civil society organizations working on health: including NGOs, associations of doctors, nurses, public health professionals and foundations on health
- International and regional organizations working on health, such as WHO and ECDC.

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