3.2 Disaster risk factors – hazards, exposure and vulnerability

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3.2.1 Learning objectives

To understand the key factors to consider when developing a study to assess risk factors relevant to health emergency and disaster risk management (Health EDRM), including:

1. How hazards, exposure, and vulnerability/capacity create disaster risk.
2. The unique challenges of defining, identifying and measuring risk in disaster research.
3. Common issues of validity and quality in causal research in disasters.
4. How to conduct a study to assess disaster risk factors.

3.2.2 Introduction

In disasters, there are three broad areas of risk to health: the hazard that can cause damage, exposure to the hazard and the vulnerability of the exposed population (see also Chapters 1.3 and 2.5) *(1)*. Disaster research often strives to show that these risks affect morbidity, mortality or well-being in some way. This provides evidence to inform decisions relevant to Health EDRM.

Causative studies look for a risk factor that, if removed, would prevent the associated adverse outcome. A hypothesis is developed to explain the relationship between exposure to the risk factor and the outcome, and assumptions are made about what other factors (usually called confounding factors) might influence the relationship. The conclusions that can be drawn depend on how well these elements are addressed and measured when conducting the study and interpreting the results.

Research on disasters requires critical reflection around choosing and measuring risk factors because of the pragmatic difficulties inherent with conducting research in disaster settings *(2)*. This chapter outlines areas of disaster risk and discuss how research can be used to determine the causes of the problem, and how these causes and the size of their effects can be measured reliably. Chapter 4.2 provides additional information on how to undertake and interpret the statistical analyses that would help with this.

3.2.3 Hazards

Disasters often follow a hazard that negatively impacts a population *(3)*. Hazards can take many forms:

Natural: earthquake, landslide, tsunami, cyclones, extreme temperatures, floods, or droughts

Biological: disease outbreaks including human, animal, and plant epidemics and pandemics

Technological: chemical and radiological agent release, explosions, and transport and infrastructure failures

Societal: conflict, stampedes, acts of terrorism, migration, and humanitarian emergencies

Many ways to classify hazards exist (see Table 3.2.1 for an example). Hazards can occur individually, sequentially or in combination with each other. A primary hazard can be followed by secondary hazards, as seen with the earthquake, tsunami, and radiological hazards in the 2011 East Japan disaster (Chapter 1.3) *(4–5)*. Timing, severity, geographic location, and frequency are important characteristics of hazards. Hazards can have a short or long duration, and can have different impacts depending on the time of day, week or month when they happen *(6)*. They can be sudden onset, like an avalanche, or develop slowly over time as the result of a combination of factors. Deforestation, for example, is a slow onset hazard which can stem from factors such as limited resource management, land use planning, economic opportunities, and climate change. Hazards can be severe in their scope and impact or small-scale and localized. Hazards can happen infrequently, like radiological incidents, or frequently, like hurricanes and typhoons. How important these characteristics are and how they are translated to risk is relative to the population exposed to the hazard. For example, areas of the southern USA frequently experience hurricanes of varying strengths. People living in mobile homes in these regions are more likely to evacuate their homes during a hurricane because they perceive their risks to be high, based on prior experience with hurricanes and the strength of the hurricane, compared to those who live in more strongly built structures *(7)*.

Table 3.2.1 Truncated WHO Classification of Hazards *(8)*

Groups	Sub-groups	Examples of main types
Natural	Geophysical	Earthquake, geophysically triggered mass movement, volcanic activity
	Hydrological	Flood, wave action, hydrometeorological triggered mass movement
	Meteorological	Storms, extreme temperature
	Climatological	Drought, wildfire, glacial lake outburst
	Biological	Air-, water-, and vector-borne diseases, animal and plant diseases, food-borne outbreaks, antimicrobial resistant microorganisms
	Extraterrestrial	Impact, space weather
Human-induced	Technological	Industrial hazard, structural collapse, fire, air pollution, infrastructure disruption, cybersecurity, hazardous materials (including radiological), food contamination
	Societal	Armed conflict, civil unrest, financial crisis, terrorism, chemical, biological, radiological, nuclear, and explosive weapons
Environmental	Environmental degradation	Erosion, deforestation, salinization, sea level rise, desertification, wetland loss/degradation, glacier retreat/melting

Case Study 3.2.1 describes the interaction of hazards with risks, using the example of earthquakes and masonry in Nepal.

Case Study 3.2.1
Structural risks during a hazard: Earthquakes and low-strength masonry in Nepal

Low-strength masonry of stone or bricks with mud mortar is the dominant building typology in Nepal and has been used as a building material since ancient times. It is still used in many parts of the country. Construction of early monuments, temples and residential buildings was generally limited to materials that were readily available and easily worked by local artisans. The trend at present is to use cement-based construction, especially in urbanizing areas.

In April 2015, an earthquake and its aftershocks killed more than 8800 people and injured more than 22 000, largely due to the damage to low-strength masonry structures. Among other factors, the impact on life depended on building vulnerability and the evolution of construction methods. Indeed, fatalities from the earthquake indicated that, on average, there had been a reduction in building vulnerability in urban areas, whereas buildings in rural areas remained highly vulnerable. A post-disaster needs assessment reported the following damage to houses associated with masonry strength *(9)*:

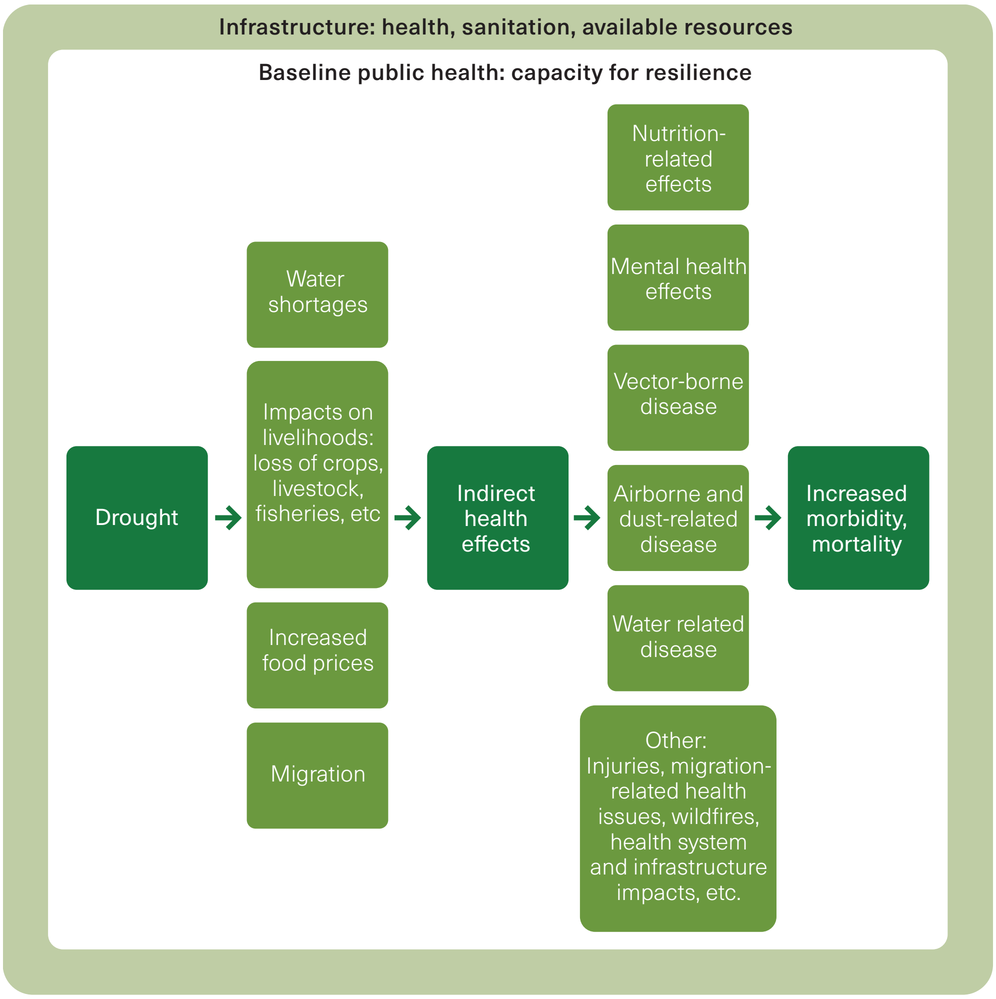
	Low-strength masonry	Cement masonry	Reinforced concrete	Total
Partially damaged	173 867	65 859	16 971	256 697
Fully damaged	474 025	18 214	6 613	498 852

The National Society for Earthquake Technology in Nepal started conducting training on earthquake resistant construction of vernacular buildings for masons in the late 1990s, and the government has taken the lead with national and international support, especially after the 2015 earthquake. There remains a continuing need for the institutionalization of a comprehensive, multi-tier and hands-on training certification programme to teach further skills in improving seismic performance of buildings and for developing nationwide capacities in earthquake-resistant reconstruction.

3.2.4 Exposure

Populations and societies need to be exposed to a hazard to be affected by it. Populations are often talked about as being directly or indirectly affected. Direct effects include injury, illness, other health effects, evacuation and displacement, and economic, social, cultural, and environmental damages. Indirect effects refer to additional consequences over time that cause unsafe or unhealthy conditions from economic, infrastructure, social, or health and psychological disruptions and changes. One of the major challenges in disaster research is measuring who has been affected and when. Determining which effects can be attributed to a disaster is complex, as there are multiple indirect pathways to an outcome (Figure 3.2.1). This is further complicated when populations are repeatedly or continuously exposed to a hazard, and when the time until the effects appear varies. For instance, disruptions to the health system and persistent stress from exposure to a hazard can lead to a greater burden of chronic conditions that may not present until months or years after a disaster.

Figure 3.2.1 Example of the indirect impact of droughts on health *(10)*



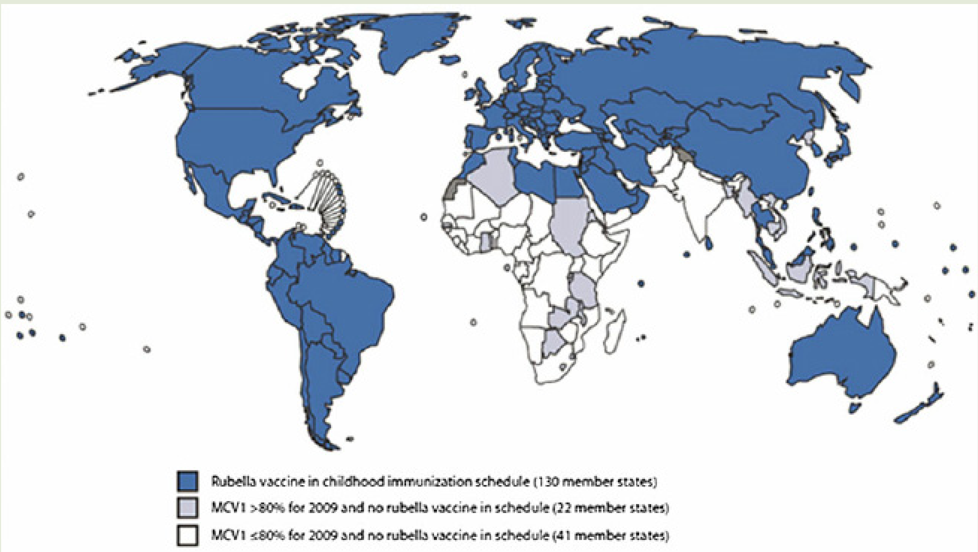
Case Study 3.2.2 shows how exposure risk can be reduced by changes to organizational behaviour.

Case Study 3.2.2
Changing organizational behaviour to reduce exposure risk: Vaccination to prevent congenital rubella syndrome

In the first half of the twentieth century, the link between infectious diseases and birth defects was not known. Rubella was a common childhood infectious disease, but also occurred in adults, including pregnant women. It was not until 1941 that the ophthalmologist Norman Gregg noticed that there were more infants with congenital eye problems that year than in the preceding years, and realized that their mothers had had rubella when pregnant. By reviewing patient records, he connected the increased number of infants with congenital eye problems he had observed to a large epidemic of rubella which had recently occurred, and went on to show that rubella in early pregnancy could be linked to many serious birth defects in children. The possibility that an apparently trivial illness could cause major birth defects like deafness, blindness, and heart defects was initially dismissed, and it took time for the association to be understood and identified as congenital rubella syndrome.

Recognizing the value of vaccination to reduce exposure risk, the number of WHO Member States using rubella vaccines in their national immunization programmes continues to grow, increasing from 83 out of 190 Member States in 1996 to 130 out of 194 in 2009 (Figure 3.2.2). As a result, rubella has been eliminated in the WHO Region of the Americas to less than 1 case of congenital rubella syndrome per 100 000 births. Developing comprehensive vaccination programmes to prevent exposure to rubella required high-level political commitment and partnerships, proven technical strategies and surveillance tools, ongoing training for surveillance staff, and recognizing outstanding performance by individual countries. (11)

Figure 3.2.2 Countries using rubella vaccine and countries meeting WHO criteria for rubella vaccination introduction, 2009



3.2.5 Vulnerability

Vulnerability and capacity are made up of a wide range of physical, social, economic, and environmental factors, and are closely tied to development *(12)*. Vulnerability is highly dependent on the context of the hazard, since it is shaped by the context's individual factors and behaviours, history, politics, culture, geography, institutions, and natural processes. This can include things such as land use, public infrastructure, the burden of disease in the population and previous exposure to hazards. What makes people vulnerable is complex, and vulnerability can be both a risk factor for and an outcome of disasters. Vulnerability is discussed in Chapter 2.5 in relation to high-risk groups but, for example, poverty can put people at risk by forcing them to live in areas highly exposed to hazards, and exposure to hazards can cause poverty by damaging assets, interrupting livelihoods, and so on. While some factors can make an entire population vulnerable, such as poor governance or corruption, others are individual or specific to certain groups. Examples include level of education, social mobility, access to economic resources, physical and mental capacity, language barriers, or formal access to protection and services (see Case Study 3.2.3). As discussed in Chapter 2.5, some groups that are commonly thought of as having higher levels of vulnerability are *(13)*:

- People living in poverty
- Women
- Children and youth
- Older people
- People with disabilities
- People with chronic illness or underlying health conditions
- Migrants
- Ethnic minorities and indigenous peoples
- Sexual minorities

Case Study 3.2.3
Understanding individual vulnerability as health risk: Cold weather impacts and the social determinants of health *(14,15).*

The health risks and impacts resulting from cold weather greatly affect the most vulnerable people in society, such as children, older people and the chronically ill. Cold temperatures increase the risk of respiratory infections, stroke, heart attack and hypothermia, for example. Most countries affected by the impacts of cold weather have developed and implement each winter a 'cold weather plan' to help institutions and individuals better prepare and respond to cold temperatures (example: Cold Weather Plan for England *(16)*). Preventing cold-related illnesses and deaths is possible but requires interventions to reduce vulnerability.

In order to understand how this could be done, a mixed methods study (Chapter 4.13) using surveys and interviews with older people was conducted in Lisbon, Portugal. The study found that the following factors are associated with vulnerability and the ability to adapt to cold weather: health status; knowing what to do during cold weather; individual awareness of vulnerability; quality of housing; costs of heating (electricity and gas); social networks; medical support; and health costs. These results provide evidence to inform policy and practice on opportunities for reducing the vulnerability of older people to cold weather. These include life-long education, knowledge sharing and learning, individualized advice by health professionals on what to do during cold weather, financial incentives to improve home insulation, subsidies to reduce the costs of heating, and improving social safety nets and activities for older people. An example of such interventions exists in the United Kingdom through the 'Keep Warm, Keep Well' initiative *(17)*. This provides financial incentives to help reduce the costs of keeping warm at home for those who cannot afford it. Other innovative policy and practice interventions are needed to assist and support individuals in reducing their vulnerability to cold weather

3.2.6 Determining and measuring risk factors

All causative studies are prone to issues around validity. Internal validity is the extent to which an individual study can answer the research question. In classic experimental research, such as a randomized trial (Chapter 4.1) the hypothesized causal factor can be manipulated to see what effect it has on the outcome (such as testing the efficacy of different dosages of a drug). Although the cause-and-effect relationship can be affected by confounding factors that are associated with the exposure and the outcome, a well-designed study will identify potential confounders and control for them. A good study will also try to reduce its selection bias and choose a study population so that the exposed and unexposed group do not differ in ways that can affect the outcome.

Typical experimental methods are difficult or impossible to apply when studying risk factors, because doing so would require the researcher to expose the population to hazards that might be harmful to them. Furthermore, in disasters, the study population and exposed group are often 'selected' by the disaster itself, depending on the geographic location of the hazard, biologic agent and route of transmission involved, and so on. Researchers are then left with the task of identifying a control group to which the exposed group can be compared, in order to see what effect the risk factor – rather than any other element – had on the outcomes of these people. Common examples are to compare the same population before and after the disaster, or to compare groups in highly affected versus less affected geographic areas. Researchers need to be keenly aware of the potential differences in risk between these groups. For example, someone studying floods and social support may select people living in a flood plain as their affected group and people living in a nearby mountainous area as their comparison group. In this case, consider how the hazard will affect each region; a larger proportion of displacement because of mudslides in the mountainous region compared to the flood plain may be a key difference between the groups that could affect social support *(18)*.

Researchers who use data collected for other reasons (often called "secondary data") (Chapter 4.4) need to think about who is missing from the data. Data that comes only from medical facilities, for instance, will not include people who were unable to access healthcare, and this population may differ substantially in health status or socioeconomic status from those who were able to do so. An example of this is an unexpected reduction in mortality after flooding that was observed in a health dataset from the UK *(19)*. The reduction may have been the result of the affected population moving away and dying in geographic locations that had not flooded and were thus not reported as dead in the dataset from the flooded area.

Identifying which risk factors to use in a study will depend on the context and outcome *(20)*. Factors must have a logical link to the outcome to be a risk. One way to help determine this is by using a source-pathway-receptor approach *(21)*. A factor (the source) may be a risk if there is a reasonable pathway for it to cause harm to a population (receptor), and if the harm in the population can be traced back to the factor. This has been used to evaluate flood risks *(22)*, where the river is the source, the floodplain is the pathway, and the people living in the floodplain are the receptor. The impact on the people living in the floodplain can be traced back to the river that flooded via the floodplain. Using risk assessments are another approach that can help to identify the relevant hazards, direct and indirect exposures, and potential vulnerabilities of interest for the context *(13)*.

Measuring risk factors requires a firm understanding of the relationship that will be assessed. A study interested in the relationship between a hazard and an outcome will need to choose which characteristics of the hazard and population are relevant for their hypothesis. Using the example of hurricane exposure and PTSD, it would be necessary to decide if it is important to study ethnicity and level of exposure to the hurricane, or if individual trauma is expected to have the same impact on the outcome as neighbourhood trauma *(23)*. Any assumptions the researcher makes about relevance need to be explicitly stated. This is a helpful way to keep the study focused, avoid introducing bias, and guide the search for information.

Careful consideration also needs to be given to how to measure a risk factor. Some risk factors, such as age, can be measured directly. Others, like social exclusion, are more open to interpretation by the researcher and study population. Directly asking a study population is one way to measure risk, but accurately and completely recalling information, events, or situations from before, during, and after a disaster is challenging, and the information received from the participants can be inaccurate and biased. For any data that are collected, the tools used to measure risk should be tested and piloted in a similar population before data collection begins. A good measurement will be reliable, and produce similar results among similar participants. Pre-validated tools do exist for certain domains, especially for psychological research *(24)*, but attention should be paid to how well the questions and concepts translate from the context where the tool was developed to the context where it will be used, and it is important to keep in mind that all factors can be measured and defined in multiple ways. This raises issues about comparability of findings among research studies that use different definitions and measurements. A good rule of thumb is to clearly state the definitions and measurements that are used in the study, and the rationale for choosing them.

External validity is the extent to which the results of a study can be applied to other situations. Thinking about external validity means acknowledging the selection bias in the study and how this may affect the results, and understanding the study setting so that the findings can be interpreted in a realistic way. This is particularly important for disaster research, when the unique combinations of hazards, exposure, and vulnerability means studies are conducted in a specific context that may not be replicable elsewhere. While a single study may have poor external validity, it is still part of a larger base of evidence that can help people to understand the relationship between a risk factor and outcome *(25)*.

3.2.7 Conclusions

Health EDRM requires a good understanding of the risk factors that, when coupled with hazards relevant to a disaster, can cause health problems and harms. Research into this needs to take account of the interaction between hazards, exposure, and vulnerability or capacity. Then, when this research is being considered by decision makers, they need to assess the study's internal validity (relating to how well it was conducted) and external validity (relating to its relevance to settings or times other than where and when the study was done).

3.2.8 Key messages

- **Disasters are a combination of hazards, exposure and vulnerability. Finding causative factors for disaster outcomes means examining risk factors in these areas.**
- **Risk factors can combine in unpredictable ways, creating a complex and unique research context. While it can be difficult, this complexity must be grasped and acknowledged if research is to be valid.**
- **When designing, conducting and using research, careful scrutiny of the definitions, measurements, and risk factors used is important to understand what conclusions can be drawn from the individual study and from the overall body of evidence.**

3.2.9 Further reading

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