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Using epidemiological principles to assess impacts of emergencies and disasters

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2.1.1 Learning objectives

To understand how data can be gathered for epidemiological research in emergencies and disasters in order to assess the risk factors and health consequences, including:

1. Sources of vulnerability and exposure to hazards.
2. Impacts of disasters on mortality and morbidity.
3. Sources of data and databases that are available for epidemiology research.
4. Value of surveillance mechanisms for epidemiological studies of disasters.

2.1.2 Introduction

To adequately describe a disaster, or any other significant health event, requires some quantification of the scale of its impact on humans and society at large: we need to describe how people's health is affected by such events and analyse the causes of those effects. Without this understanding of the problem, we are not equipped to develop targeted measures – in health and other sectors – to reduce risks before, during and after emergencies.

Epidemiological studies can help us with this by investigating the distribution and determinants of health or disease. Epidemiological studies may also identify ways to prevent diseases and other health problems at source, to control them or to mitigate their effects. Ideally, studies should investigate the long-term impacts of disasters, but this is rare, with most studies focusing on the immediate effects (typically those during the first year).

Applying the principles of epidemiology to the study of the determinants and the effects of disasters on human populations is crucial. It provides some of the evidence base for effective health emergency and disaster risk management (Health EDRM), and it includes assessment of the adverse health effects of disasters, analysis of the risk factors that affect exposure and vulnerability to hazards, and of the capacities of individuals, communities and institutions to manage these risks. The aim of such analyses is to inform preparedness and response efforts, recovery strategies and – crucially – to help to explain, predict and mitigate the consequences of future disasters by allowing the development of targeted measures to prevent and reduce hazards as well as the exposures and vulnerabilities of populations at risk.

Epidemiology is a vital tool for situational awareness, which in disaster settings provides much needed information to allow the identification of population needs, plan a response and gather appropriate resources. The main objectives of disaster epidemiology are therefore:

- to prevent or reduce the number of deaths, illnesses, and injuries caused by disasters;
- to provide timely and accurate health information for decision-makers and practitioners to improve risk assessments, prevention, mitigation, preparedness, response and recovery strategies;
- to provide a fundamental body of evidence on the health impacts of disasters that can be used for research and evaluations *(1).*

WHO estimates that, in the last decade, more than 2.6 billion people have been affected by disasters such as earthquakes, tsunamis, landslides, cyclones, heat waves, floods, or severe cold weather *(2)*. This chapter outlines some of the methods that may be used to arrive at such a figure and to study the factors that contribute to this burden.

Disasters may lead to displacement of populations, disruption to health systems and damage to health infrastructure. Each of these has consequences for public health, including increased mortality, deteriorating mental health, outbreaks of infectious diseases and acute malnutrition. Such consequences are all more severe when people are living in high density, frequently temporary settlements with insufficient food, water, housing or sanitation *(3–5)*. Furthermore, displaced people are at increased risk of violence, including sexual and gender-based violence.

A range of expertise is needed to manage the risks of a variety of public health problems. These include specialists in vaccine-preventable and other infectious diseases, water, sanitation, and hygiene (WASH), nutrition, injury, sexual health, and mental health — as well as leaders, managers, emergency service personnel, risk communicators, logisticians, and evaluators in health and other sectors. Identifying the different health impacts of disasters and the causes of these impacts may require a similarly broad range of methods. Using epidemiological principles to underpin surveillance for research in disaster settings is largely contingent on recognizing opportunities when they occur to collect actionable information that can be used for developing or evaluating interventions to preserve health and save lives (for example, identifying the first cases of measles or diarrheal disease in a camp).

Epidemiological assessments might involve analysing risk factors and studying health outcomes, but the tasks required for this are rendered especially complex because of the involvement of many different agencies, using non-aligned data collection systems. Furthermore, data may be collected, collated or stored at some distance from the location of the initial disaster. These challenges need to be considered carefully when designing an epidemiological study — and are discussed in this chapter. Some of the key techniques for disaster epidemiologists include assessments of need (which may require rapid assessment), health surveillance, the use of registries of affected individuals and assessment of outbreaks and other cascading hazards that may follow the initial event.

2.1.3 Rapid needs assessments

One of the key pieces of epidemiological research to undertake — and one that is normally applied in a sudden-impact emergency and disaster situation — may be to assess the immediate impact on the health of the affected population and their consequent healthcare needs.

Rapid needs assessments employ survey and population sampling methods to determine the health status and basic needs of those in the area affected by a sudden-impact disaster. The use of appropriate sampling provides epidemiological rigour and a rationale on which to base planning, operational response and resourcing decisions. Care must be taken to ensure that the population sampled is truly representative of the wider population for whom the findings will be extrapolated. Furthermore, because limited comprehensive information is typically available on the consequences, scale and severity of the disaster at the time of impact, the use of reliable epidemiological methods may be important in preventing undue reliance on data gathered by responders who may be working independently or without coordination. Nonetheless, the purpose of the rapid needs assessment is to provide an opportunity to collate what data might be available, even if such informal data gathering may result in assessments that are incomplete, conflicting or unreliable.

One of the survey tools that might be used to gather data for epidemiological research is the Multi-Cluster/Sector Initial Rapid Assessment (MIRA). This was developed by the Inter-Agency Standing Committee (IASC)'s Needs Assessment Task Force (NATF) and is an example of a system to facilitate a rapid needs assessment. It seeks to address the problem of conflicting findings from needs assessments conducted by different crisis responders within and between sectors *(6)*.

A MIRA can be carried out jointly by key stakeholders in a short period of time (days or weeks) and aims to provide a foundation of commonly understood information about the affected population and their needs. It may also support the identification of information sources in the early stages of the process, which can be used to support prioritization of the humanitarian response and immediate development of a strategy through three components:

i) The systematic collation and analysis of secondary data, which may initially be the only information available and which were collected for other reasons — epidemiological methods can be used to analyse these data in order to describe the extent of the disaster, the number of affected people and places, and allow articulation of immediate priorities, bearing in mind the identified hazards and risk factors.

ii) Community level assessment, which is a standard approach for collecting and analysing new or primary data — this allows agencies to integrate the needs and priorities of affected communities into the broader assessment of strategic humanitarian priorities. Such community level assessments are limited to those communities that can be found or accessed and as such must be considered in the context of the secondary data analysis noted above.

iii) Collation and analysis of all data and information following an agreed structure, which analyses and describes the primary and secondary data obtained by all agencies or responders.

2.1.4 Health and health facility surveillance

Many countries have their own national or regional systems for health surveillance, which are vital during outbreaks, disasters from natural and technological hazards, and conflicts. In public health, this surveillance includes the systematic collection, analysis and interpretation of health-related data for the planning, implementation, and evaluation of public health practice. Such surveillance can serve as an early warning system for an impending outbreak, help target response efforts, document the impact of an intervention, monitor and clarify the extent of health problems and allow priorities to be set and public health policy and strategies to be implemented based on quantitative evidence. For example, surveillance of vaccine-preventable diseases, such as measles, is vital for managing a potential outbreak, as well as in disaster or conflict settings, in order to understand the functioning of the wider health system and recognize weaknesses early.

Disasters and other complex emergencies often increase the risk of transmission of infectious diseases and make other health problems (such as severe malnutrition) more likely. An effective disease surveillance system is essential to detecting disease outbreaks quickly before they become difficult to control. However, if the routine system is adversely affected by the impact of the disaster or is not designed to gather information relating to the health consequences of the hazards that led to the disaster or arise in its aftermath, a more specialized system may be needed.

A recent example of the development of one such specific surveillance tool is WHO's Early Warning, Alert and Response System (EWARS) (see Case Study 2.2.1). This was designed to improve disease outbreak detection in emergency settings, such as in countries experiencing an outbreak in another part of the country, in conflict or following a disaster caused by natural hazards *(7)*.

'EWARS in a box' was developed by WHO to strengthen the gathering of health data in outbreaks, disasters and other emergencies, and may provide an important means of gathering the data needed for epidemiological research. It is an emergency kit containing the equipment needed to rapidly establish early warning, alert and response activities, particularly in difficult and remote field settings without reliable internet or electricity. It has been used across the world, including in the response to cyclone Idai in Mozambique in 2019 *(8)*.

The box contains 60 mobile phones, laptops and a local server to collect, report and manage disease data. A solar generator and solar chargers allow the phones and laptops to be powered without mains electricity. Each health facility can be allocated a mobile phone with a disease reporting app that will allow health workers to enter data on patients with symptoms of priority diseases or conditions such as acute diarrhoea, cholera, measles, acute flaccid paralysis, fever, malaria and jaundice. The app uploads the information to a server, where the data is used to generate real-time reports. This allows a rapid response to emerging diseases as well as allowing aggregated reports from health facilities, automatic triggering and investigation of alerts, collation of lists of all known and suspected cases (line lists) during outbreaks and recording of verification and risk assessment activities.

Where possible, health surveillance should rely on existing systems and processes as, when these are functioning, they can provide the most reliable and timely information (*9–10*). Such systems gather information on a routine basis from hospitals, primary care settings and laboratories, but may need amendments or augmentations to enable them to rapidly detect diseases of the highest priority and consequence in a disaster, which may differ markedly from those the systems were established to detect.

Healthcare surveillance systems make it possible to measure demand for services and identify where emergency or other healthcare resources may become stretched or overrun. Syndromic surveillance systems (see Chapter 4.9), such as England's National Ambulance Surveillance System, can be used to reveal early information about unfolding incidents and outbreaks *(11)*. Monitoring of calls to poison centres may allow identification of public exposure or concern about chemicals or other environmental hazards *(12)*.

However, although such systems may be a feature of high-income countries, they may not be in place in some low- and middle-income countries, or they may be particularly susceptible to the impact of disasters on staffing and infrastructure. For example, recurring outbreaks in the African region have led to recognition of the need for outbreak response tools that can be implemented during complex emergencies when existing national public health surveillance systems may be underperforming, disrupted or non-existent. Existing national public health surveillance systems may quickly become overwhelmed and unable to meet the surveillance information needs of a large-scale outbreak, conflict or disaster. In addition, existing tools may not be sufficiently comprehensive, or address requirements in the field during emergencies, which can lead to proliferation and fragmentation of data collection at the frontline. This can make it especially important for those designing epidemiological research to take particular account of the quality of the data, and decide whether the data from routine health and health facility surveillance systems is sufficiently reliable.

To illustrate how epidemiological research needs to use methods that supplement routine data, Case Study 2.1.1 describes how a variety of epidemiological studies were used to estimate the number of deaths caused by Hurricane Maria in Puerto Rico.

Case Study 2.1.1
Mortality estimates from Hurricane Maria in Puerto Rico

Puerto Rico is a part of the USA in the northeast Caribbean Sea, with a population of approximately 3.3 million.

Hurricane Maria, a category 4 hurricane, hit Puerto Rico on 20 September 2017. Widespread damage affected the healthcare system and caused power outages. By the end of 2017 the number of deaths was estimated as 64 *(13)*, but this only considered deaths for which a "hurricane related" cause of death was recorded on the person's death certificate. Although this would be a standard epidemiological technique for using routine data to determine the number of deaths due to a specific cause, this method of measurement may be unreliable in the disaster context.

For example, a study published in May 2018 *(14)* estimated the number of excess deaths to be close to 6000, with most of these deaths resulting from the interruption of services such as health care, electricity, and water access. This epidemiological study gathered its data through a household survey, extrapolated the household mortality rate to the complete population and compared this to the mortality rate for the same period in 2016.

In a subsequent study *(15)*, data from before Hurricane Maria were used to estimate an average number of expected deaths per month. This generated a conservative estimate of 1139 excess deaths, with levels returning to the pre-hurricane range by December 2017, three months after the hurricane.

Finally, an independent review commissioned by the government used the official, national statistics to estimate the total excess number of deaths after the disaster. This reported that there were 1427 more deaths in the four months after the hurricane than the number expected using data from the previous four years *(16)*.

These different ways of estimating the number of deaths caused by the hurricane illustrate the potential impact of using different techniques for epidemiological research. They vary from counts based on death certificates in the immediate aftermath of the hurricane to estimates based on comparisons with the same months in previous years. This is important when considering the implications of epidemiological research — the updated estimate from the government-commissioned review prompted the government to undertake a major review of its preparedness, which should help to inform future planning and the public health preparation and response to such a disaster in the future.

2.1.5 Outbreak investigations and other incident reports

Outside the context of disasters from natural hazards, conflicts and other emergencies, epidemiological methods are used to investigate disease outbreaks, employing both descriptive and analytical techniques to understand the source of a disease or infection, how it may be spreading and how best to control it. This may allow interventions to be put in place to prevent further morbidity and mortality. These studies include assessments of the prevalence of biological and pathogenic hazards and of the health consequences already known to be caused by them, as well as investigations that test the association between hazards and health outcomes to investigate whether these hazards lead to the health outcomes.

These epidemiological methods can also be important in disasters from natural hazards where, for example, population movements or damage to healthcare infrastructure can lead to the more rapid spread of infectious diseases. Epidemiological studies can use exposure data to determine the presence of these risk factors and assess the effects of an intervention. For example, case control studies in Haiti in 2012-14 found that a reactive cholera vaccination programme provided protection from four to 24 months after vaccination. This was important because vaccination is a key component of efforts to control cholera epidemics *(17).*

In some cases, investigations may take place long after the acute disaster phase, as health impacts and the research needed to investigate them may take some time to be identified. For example, epidemiological techniques such as case control and cohort studies were employed to look for risk factors for traumatic injury after an earthquake in California. These longer term studies found that peak ground acceleration, perceived shaking intensity, building characteristics, and individual characteristics were important risk factors for injury *(18–19).*

Case Study 2.1.2 provides an example of how epidemiological methods were used to study long-term environmental contamination and the outbreak investigation mechanisms needed to determine cause and effect, as well as the control systems that had to be put in place.

Case Study 2.1.2
Minamata Bay and organic mercury poisoning

Between 1932 and 1968, it was reported that an estimated 27 tons of mercury was released into Minamata Bay *(20)*.

In the 1950s, initial reports of poisoning involved local cats, birds and fish *(20)*. By the middle of the decade, symptoms started to appear in humans: these included loss of fine motor control, stumbling while walking, and violent tremors *(21)*. Using a wide range of epidemiological techniques including surveys, case interviews and descriptive and analytical epidemiological studies, a link was made with consumption of contaminated fish *(22)*.

Organic mercury was identified as the cause in 1959.

The findings of these studies contributed to a global treaty, the Minamata Convention on Mercury, seeks to protect human health and the environment from the adverse effects of mercury *(23)*.

2.1.6 Databases holding disaster data

Some of the epidemiological research relevant to emergencies and disasters is able to draw on data included in disaster databases. These present exciting opportunities for disaster epidemiology but also highlight some challenges. Despite containing large amounts of data from emergencies and disasters that can be analysed and reported, they reflect the shortcomings in the data itself. These include a lack of standardization in collection methodologies and definitions, and the absence of a single reliable source of verified data *(24)*. Moreover, the databases are hosted by a variety of organizations, with different disciplinary affiliations and scientific traditions. Individual databases are usually set up with distinct objectives, which may be inconsistent with those of other databases. This makes it difficult to compare outputs across databases, as has been shown in several comparisons *(25–26)*. This lack of a shared focus makes it difficult to come to a consensus on the range and magnitude of impacts and, as a result, to have confidence in the estimates presented *(27)*. Described below are two of the main disaster databases (EM-DAT, from CRED, and the Desinventar), followed by information on the Sendai Framework Monitor (SFM), which has recently been developed with the intention of providing a more complete and shared global database on disasters, aligned with the targets of the Sendai Framework for Disaster Risk Reduction 2015-2030 *(28)*.

2.1

CRED and EM-DAT (Emergency Events Database)
The Centre for Research on the Epidemiology of Disasters (CRED) was established in 1973 as a non-profit institution, with international status under Belgian Law. It is located in the School of Public Health of the Université Catholique de Louvain in Brussels. In 1988, **CRED** launched the Emergency Events Database (EM-DAT). This widely used and cited database was until recently fully accessible to the public. It provides information on the human impact of disasters, including the number of people killed, injured or affected; as well as economic damage estimates and disaster-specific international aid contributions.

For a disaster to be entered into the database, at least one of the following criteria must be fulfilled:

- At least ten people reported killed
- At least 100 people reported affected
- Declaration of a state of emergency
- Call for international assistance.

EM-DAT contains core data on the occurrence and effects of more than 15 700 disasters from 1900 to present, including those caused by natural and technological hazards. The database is compiled from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies. However, the eligibility criteria for EM-DAT mean that it does not include data on the large number of smaller events that occur each year that do not meet at least one of the four eligibility criteria. It is also hampered by the issues surrounding disaster data generally, namely the challenges of capturing data on all disaster events and the potential unreliability of data and reports on health impacts, including mortality.

DesInventar: a Disaster Loss Database
In the early 1990s, groups of researchers, academics, and institutional actors in Latin America linked to the Network of Social Studies in the Prevention of Disasters in Latin America (Red de Estudios Sociales en Prevención de Desastres en América Latina - LA RED) worked together to develop DesInventar, a conceptual and methodological tool for generating National Disaster Inventories and constructing databases of information on damage, losses and other effects of disasters on specific countries. Subsequently, UNDP and UNISDR sponsored implementation of DesInventar in the Caribbean, Asia and Africa. Desinventar includes:

- Methodology (definitions and help in the management of data)
- Database with flexible structure
- Software for input into the database.

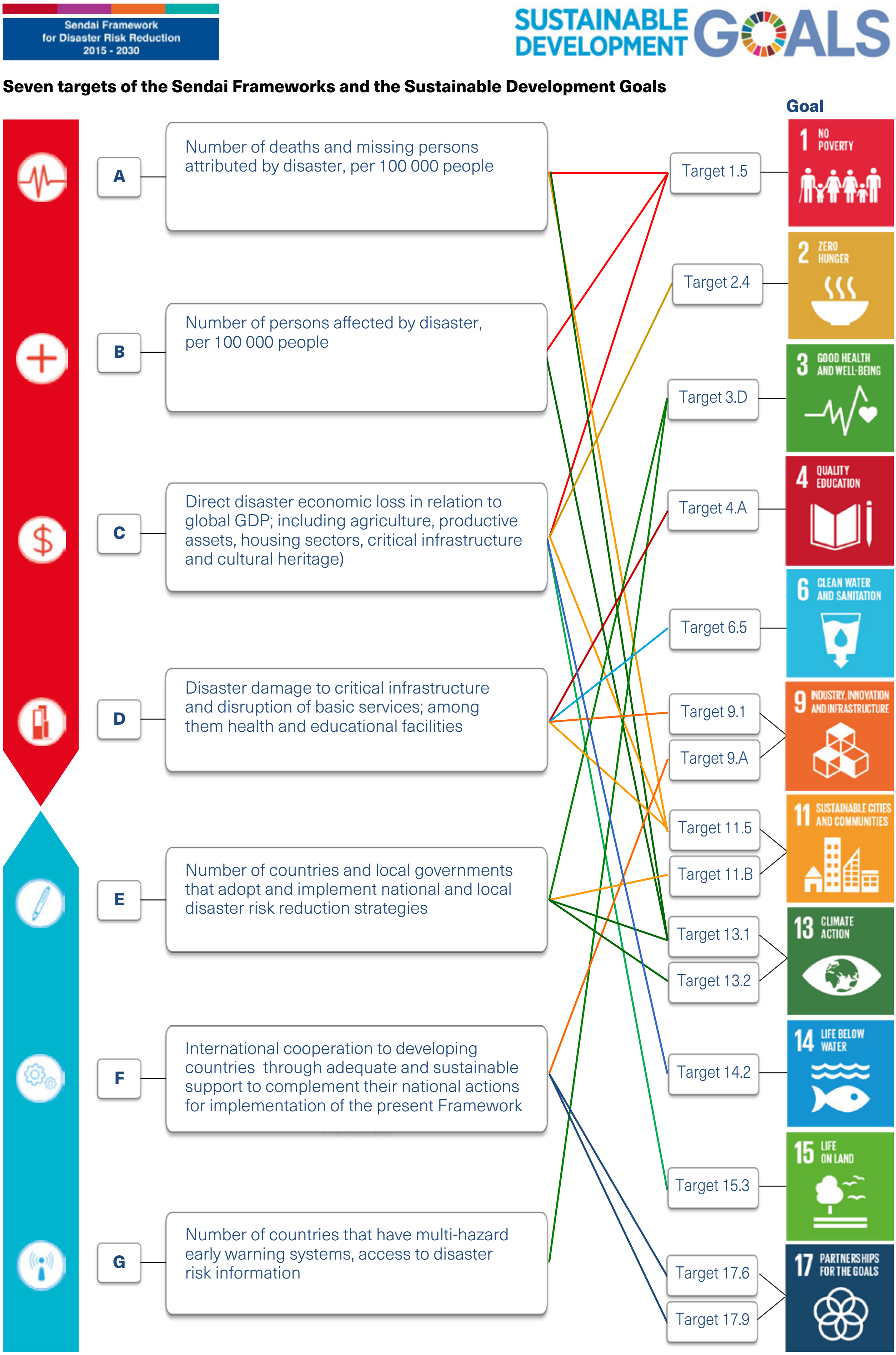
The information in DesInventar inventories is spatially disaggregated in order to show (and later analyse) the effects of disasters at a local level. The minimum disaggregation level recommended for country-level disaster inventories is equivalent to municipality, which is usually one or two levels below the country's first-level administrative or political division (province, state or department depending on the country). A list of the available databases from reporting counties is available on the DesInventar website and DesInventar has been linked to reporting for the Sendai Framework Monitor.

Sendai Framework Monitor
UNDRR has identified strong accountability as a corner stone of the Sendai Framework for Disaster Risk Reduction 2015-2030 *(28)*. A set of 38 indicators, recommended by an intergovernmental expert working group, are being used to track progress in implementing the seven targets of the Sendai Framework, as well as its related dimensions reflected in the Sustainable Development Goals (Figure 2.1.1). The Sendai Framework Monitor will also function as a management tool to help countries document their disasters, in order to facilitate their understanding of which disaster risk reduction strategies may be beneficial, assist in risk-informed policy decisions and inform the allocation of resources to prevent new disaster risks.

UNDRR is implementing a system to determine progress in implementing the Sendai Framework and this will be assessed every two years. As of March 2018, UN member states must use the online Sendai Framework Monitor to report against the indicators for measuring the global targets of the Sendai Framework. A detailed timeline has been developed and shared for the key milestones of the process and 84 of 195 countries had started to report as of August 2019.

The Sendai Framework Monitor is a major outcome of the Sendai Framework for Disaster Risk Reduction, which should provide more complete systematic information about the occurrence of all disasters, including those of small and medium impact. It should provide disaggregated data about the effects of large scale disasters that has not previously been available for most countries.

Figure 2.1.1 Links between Sendai Framework reporting and the Sustainable Development Agenda



2.1.7 Value of disaster epidemiology for research

Epidemiological research can be used to generate knowledge long after a disaster response effort has passed. It might help to fill evidence gaps that are identified by the evaluation of the response, as well as identify further gaps that need to be filled. Although many public health and other disaster responders may have no or few resources to commit to formal epidemiological studies or research, the role of initial needs assessments, surveillance and incident investigations is vital in informing the later strategy for knowledge generation. By using existing data from, for example, surveillance systems or disaster databases as mentioned above, researchers can minimize the research waste that might arise from them conducting their own data gathering, such as through new surveys. Researchers need to be part of collaborations between responding agencies, academic institutions, government agencies and funding bodies to help them to understand the benefits and shortcomings of using existing data and to identify priority areas for new research. These partnerships are critical to ensuring that opportunities to improve future disaster response are taken. By way of illustration, Case Study 2.1.3 shows how epidemiological research provided important evidence on the mental health impacts of flooding in the UK.

Case Study 2.1.3
Measuring mental health impacts of flooding

After widespread flooding in England in 2013-14, a multi-year National Study of Flooding and Health was established to examine the long-term impact of flooding on the mental health of people living in flood-affected areas.

The methodological complexities of measuring mental health impacts of flooding meant that collecting data on a range of personal factors was essential. A year after the flooding, the epidemiological research showed psychological morbidity was elevated among both flooded participants (prevalence of depression 20.1%, anxiety 28.3%, PTSD 36.2%) and those who were disrupted but without floodwater entering their homes (prevalence of depression 9.6%, anxiety 10.7% PTSD 15.2%) *(29)*. The prevalence of depression, anxiety and PTSD among unaffected respondents living in the same area were 5.8%, 6.5% and 7.9% respectively.

Furthermore, flooded participants who reported disruption to domestic utilities (such as electricity, gas or water) or to health care were more likely to have developed symptoms of one of these mental health problems than other flooded participants. For example, after adjusting for the depth and duration of floodwater in the home, the odds of probable depression were 1.7 times higher for participants who were displaced compared with those who were not *(30)*. The amount of warning received appeared to be a protective factor amongst those who were displaced, with those receiving no warning before flooding reporting more symptoms of depression and PTSD than those who were forewarned.

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2.1.8 Conclusions

Public health research is essential in determining and understanding health impacts from disasters and other emergencies. Epidemiological research provides the evidence to help decision makers plan for future disasters, showing both the causes and consequences of hazards that cause disasters and arise from them. Key epidemiological techniques for disaster research include assessments of need, health surveillance, registries of affected populations and new studies into outbreaks and other cascading hazards that may follow the initial event. Tools such as the IASC NATF Multi-Cluster/Sector Initial Rapid Assessment (MIRA) and the WHO's Early Warning, Alert and Response System (described above) can contribute to reliable research in Health EDRM.

2.1.9 Key messages

- **The principles of epidemiology for emergencies and disasters are critical to understanding risk factors and health impacts of disasters and informing strategies for health emergency and disaster risk management.**
- **Disaster databases are important sources of data but have limitations that need to be recognized by researchers and it is hoped that the Sendai Framework Monitor will help overcome some of these problems**
- **Health impacts of disasters can be both immediate and long term; the long-term impact has been relatively under-studied and thus the burden on a population is likely to be under-estimated and inadequately addressed.**

2.1.10 Further reading and resources

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