Natural Disasters and Health Risks of First Responders

Katie Subbotina and Nirupama Agrawal

Abstract The main objective of this chapter is to provide information on health risks for organizations responding to natural disasters to ensure better preparedness of their responders. Organizational preparedness has to include considerations for the type of event responders are deploying to, health risks they may be exposed to, and how they could help affected local vulnerable population. Organizations should consider preparedness of their responders with the same precision as businesses consider business continuity plans. Organizations should prioritize and specialize in the types of disasters they respond to and deliberately expand their scope as their preparedness level matures. Three case studies are presented to demonstrate the various situations and related health risks.

Keywords Natural Hazards • Health risks • First responders

1 Introduction

> *Floods wash away the surface of society. They expose the underlying power structures, the injustices, the patterns of corruption, and the unacknowledged inequalities.* (Birn et al. 2009 p 370).

The United Nations International Strategy for Disaster Risk Reduction (UNISDR) has defined disasters as: "a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses which exceeds the ability of the affected community or society to cope using its own resources" (UNISDR 2009). It is a comprehensive definition that touches upon societal dependencies and inability to restore them in a timely manner. This definition does not narrow the scope of a disaster by compiling a list of types of events that

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could occur; rather, it allows for each community to define disaster based on their vulnerabilities and threats. For the purpose of this chapter, disaster definition is going to be narrowed to focus on health risks and is borrowed from a paper on "the role of the epidemiologist in natural disasters", by Sue Binder and Lee M. Sanderson. It states that a disaster is an "event that causes adverse health impacts on a population; usually, but not always, caused widespread destruction to the environment; and occurs suddenly or ever a relatively short period of time".

This chapter focuses on the studies of such health impacts to a population of first responders.

Natural systems, which are comprised of wind, water, and earth processes, function independently of social systems, and disasters occur only when the two intersect (Burton et al. 1993). Their interaction does not have to result in an adverse consequence and can be beneficial to the exposed population if they are properly protected. For example, a flood does not have to be destructive. It fertilizes the land, flushes out salts and toxins, recharges ground waters, and deposits sediment, among other benefits (Few 2003). However, in order to decrease human suffering from floods, which are considered one of the costliest disasters, mitigation and preparedness measures need to be adapted by vulnerable communities. These measures can include early warning system to allow people to prepare or evacuate and not be harmed, channel controls such as dykes and flood walls, as well as upstream water retention (dams and reservoirs), et cetera. It is at the intersection of natural events and vulnerable populations that negative consequences occur in the form of loss of life, property and livelihood. An affected population will need immediate response and eventual recovery resources, and that is when international assistance might be required.

Disaster data is retrieved from the International Disaster Database, where criteria for a disaster definition includes any one of the following conditions to be met, "10 or more people killed; 100 or more people affected; declaration of a state of emergency; and call for international assistance" (EMDAT 2017). When comparing data to other databases it is important to consider definitions and their effects on the search outcome. For example, Public Safety Canada identifies that in order to be defined as a disaster an event has to meet one or more of the following criteria: "10 or more people killed; 100 or more people affected/ injured/ infected/ evacuated or homeless; an appeal for national/international assistance; historical significance; and significant damage/interruption of normal processes such that the community affected cannot recover on its own" (PSC 2014, database). The two databases have similar parameters for declaring a disaster but differ in the implications following an event. These differences can have an impact on the number of disasters listed and have to be considered in order to decide if the results are comparable. However, for simplicity of data analysis statistics from only International Disaster Databased are considered in this chapter.

The chapter begins with classification of disasters and their impact on health; various backgrounds of first responders, such as local, national, and international; specific health risks related to various types of disasters; and finally, cases studies follow the suit highlighting the necessity to understand health risks not only based on the type of a disaster, but also geomorphology and geopolitics of the affected area.

2 Natural Disasters Classification

An overview of disaster classification serves as a reminder that disasters are generally divided into natural, human-caused or technological events. Human-caused events can be intentional such as terrorist attacks. Technological events can also be intentional when an act of malice is carried out using technology; or unintentional which can be due to human errors or a consequence of a natural event. For example, the March 11, 2011 a 9.0 magnitude earthquake on the east coast of Japan generated a tsunami that caused the meltdown of a nuclear power plant nearby. The event caused a long term and widespread emergency in the region due to high levels of radiation (World Nuclear Association 2017). Such unintentional events following a natural disaster are defined by experts as NATECH events, which can release small or large amounts of hazardous materials into the air. Such releases from plants or industrial sites lead to higher health risks for the exposed population (Young et al. 2004). NATECH events are mainly preventable if appropriate actions are taken prior to disasters. In this chapter, the focus will be on natural disasters as the primary event and secondary events can include either other natural disasters or NATECH events, as both play a significant role in the health risk of first responders.

Natural disasters are usually studied according to their phenomena of occurrence in their respective fields of studies. For instance, hydrologists study floods, while geologists and seismologists study earthquakes (Burton et al. 1993). Due to this historical division of studies, natural disasters are classified according to the natural process. As a result, breaking natural disasters into Hydrometeorological, Geological, and Biological events seems appropriate. Hydrometeorological events include water and weather related hazards such as drought, flood, and severe storms. Geological hazards consist of avalanches, earthquakes, and tsunami events. Biological events are divided into floral and faunal events. Floral events include fungal diseases, and faunal events include bacterial, viral and protozoal diseases as well as infestations.

The international disaster database, EM-DAT distinguishes between Geophysical, Meteorological, Hydrological, Climatological and Biological groups based on the triggering event. Each group is further divided into types and sub-types. For example, the Geophysical group is divided into earthquakes, volcanoes, and mass movement (dry) types. Sub-type for mass movement (dry) includes rock fall, avalanche, landslide, and subsidence sup-types. In turn, landslide is further sub-sub divided into mudslide, lahar, and debris flow (EM-DAT 2016).

Other classifications of natural disasters include according to their characteristics, such as speed of onset, magnitude, frequency, duration, areal extent, and spatial dispersion (Burton et al. 1993). Based on this system, all hazards can be divided into Permanent (e.g. tides, erosion) that continuously occur as a normal natural process, Evanescent (e.g. climate change, drought), with no clear beginning and no clear end, and Episodic (e.g. earthquake, floods, landslides, etc.).

Some of the simpler classifications include subterranean stress, surface instability, high winds, or abnormal precipitation or temperatures (Binder and Sanderson 1987). Depending on the research question, a researcher might choose to classify disasters according to any of the systems.

Natural disasters do not always happen independently and usually lead to secondary disasters, either natural or NATECH, which will affect types of health risks they are associated with. In this section, each type of natural disaster will be explored, along with their health risks, and an associated example. Table 1 summarizes global data collected from EM-DAT (2017) website between years 2000 and 2015 pertaining to the types of natural disasters that will be discussed in this section. Data is collected on the occurrence, deaths, number of affected, injured, and homeless people, as well as monetary damage caused by the event.

Occurrence of natural disasters is not evenly distributed. Hydrological disasters constitute 44% of all natural disasters (Fig. 1), while geophysical disasters happen approximately 8% of the time. This uneven distribution requires more intense preparation for commonly occurring disasters, indicating that hydrological events should receive special consideration during training and deployment preparations.

A distribution of natural disaster consequences is summarized in Fig. 2. This presentation depicts the relative distribution of damage associated with each type of a disaster. In this view, biological disaster causes many injuries and deaths; however it does not affect too many individuals, and doesn't render many people homeless. Hydrological disasters, on the other hand, affect a lot of people and leave many homeless, while not causing as many injuries or deaths. Each disaster, thus, presents unique distribution of consequences and adequate preparation depends on understanding health risks associated with each type of disaster. The rest of Section 2 delves deeper into each disaster class.

2.1 Hydrological

Hydrological events (Table 2) are defined as "events caused by the deviations in the normal water cycle and/or overflow of bodies of water caused by wind set-up" (UN 2014). Following the EM-DAT (2017) system, these events are further divided into flood and wet mass movement (rock fall), landslides and subsidence.

The same website calculates that there were 2936 hydrological events globally between the years of 2000 and 2015, causing 103,001 deaths, and affecting 1.4 million people (Table 3).

Table 1 Global data on occurrence, deaths, number of affected, injured and homeless people, as well as amount of damage caused by the type of a disaster between years 2000 and 2015

Type	Occurrence	Deaths	Affected	Injured	Homeless	Damage($)
Biological	772	90,197	10,034,832	491,794	–	120,000
Climatological	467	22,123	986,259,050	5486	59,272	113,194,494
Geophysical	547	714,466	100,435,540	1,440,279	12,609,185	493,655,203
Hydrological	2936	103,001	1,436,360,013	287,097	16,604,621	427,104,065
Meteorological	1993	352,114	634,424,869	2,280,316	6,462,869	799,479,765
Total	6715	1,281,901	3,167,514,304	4,504,972	35,735,947	1,833,553,527

Data collected from EM-DAT database

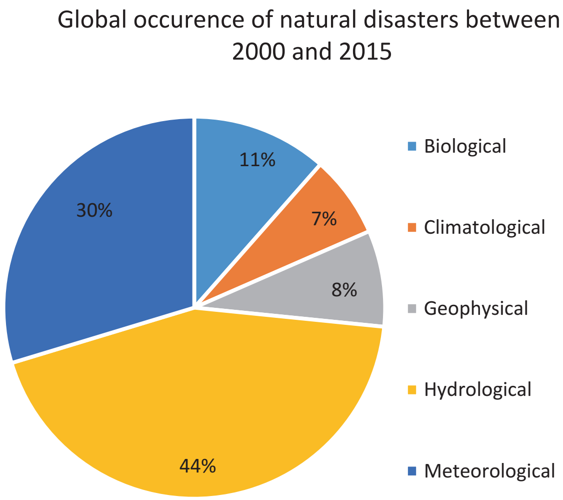

Fig. 1 Global distribution of types of natural disasters between the years of 2000 and 2015 (Data compiled from EM-DAT website)

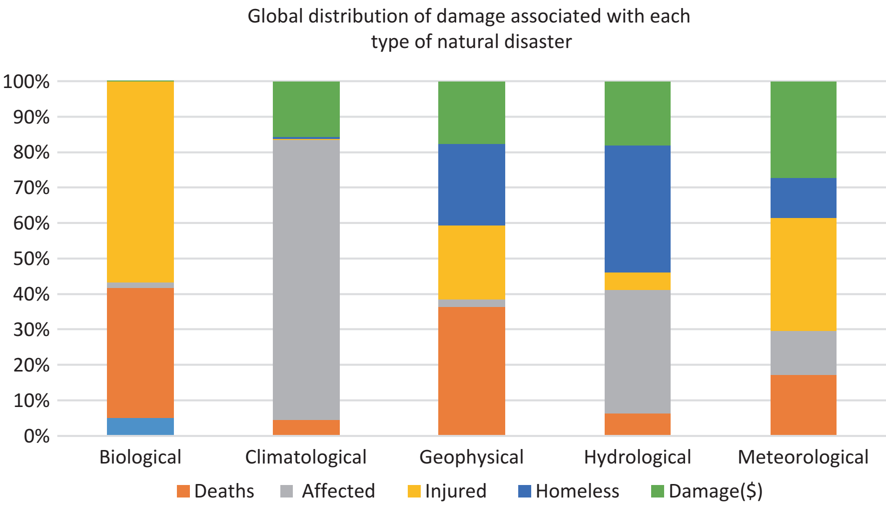

Fig. 2 Relative consequences of natural disasters divided into their types (Data gathered from EM-DAT website)

2.2 Meteorological

EM-DAT defines meteorological disasters as events that are caused by short-lived or small to meso-scale atmospheric processes that can last from minutes to days. Examples of meteorological disasters are storms, which can be tropical, extra-tropical or local as depicted in Table 4.

Table 2 Table adapted from EM-DAT

Class	Type	Sub-Type
Hydrological *(events caused by deviations in the normal water cycle and/or overflow of bodies of water caused by wind set-up)*	Flood	General River flood
		Flash flood
		Storm surge/coastal flood
	Wet mass movement	Rockall
	Landslide	Debris flow
		Debris avalanche
	Subsidence	Sudden subsidence
		Long-lasting subsidence

Retrieved from: http://www.emdat.be/frequently-asked-questions

Meteorological disasters are the second most common type of disaster to occur globally since 2000. Out of these disasters tropical storms are the most devastating since they cause the most damage, deaths and affect the highest number of people. Local storms have the second highest frequency and also hold second place in all other criteria (Table 5).

2.3 *Climatological*

Climatological disasters are events caused by long-lived, meso to macro scale processes, which can cause up to multi-decadal climate variability (EM-DAT 2017). Events in this class of natural disasters include heat and cold waves, extreme winter conditions, drought, as well as wild fire as summarized in Table 6.

Of all climatological disasters, drought occurs most often, followed by cold wave, and forest fires. In recent history, droughts also affect the most people and caused the highest amount of damage, while cold waves caused the most deaths (Table 7).

2.4 *Biophysical*

Biological disasters are defined by EM-DAT (2017) as “an exposure of living organisms to germs and toxic substances”, this definition includes insect infestation. Human activity, in particular international travel and trade, has introduced and transported alien species to new areas, which have altered normal functionality of the ecosystems and threaten native species (Ricciardi et al. 2011) (Table 8).

Biological disasters have caused $120,000 in damage according to EM-DAT; however, according to Natural Resources Canada, the cost of the emerald ash borer

Table 3 Data gathered from EM-DAT based on hydrological events from years 2000 to 2015

Type	Occurrence	Deaths	Affected	Injured	Homeless	Total damage	% of total
Hydrological	2936	103,001	1,436,360,013	287,097	16,604,621	427,104,065	
Flood	243	3606	29,716,530	2245	428,061	19,852,611	8.28
Coastal flood	41	606	10,382,313	386	22,335	8,369,462	1.4
Flash flood	419	16,168	146,425,783	53,307	1,168,372	45,799,339	14.3
Riverine flood	1934	68,489	1,246,160,626	228,471	14,560,022	350,349,868	65.87
Landslide	263	12,331	3,632,943	2374	418,826	2,679,785	8.96
Avalanche	33	1469	39,018	276	6950	53,000	1.12
Subsidence	1	287	2800	38	0	0	0.03
Rock fall	2	45	0	0	55	0	0.07

Retrieved from: http://www.emdat.be/advanced_search/index.html

Table 4 Table adapted from information available on EM-DAT website: http://www.emdat.be/

Class	Type	Sub-type	Sub-sub type
Meteorological *(events caused by short-lived/small to mesoscale atmospheric processes in the spectrum from minutes to days)*	Storm	Tropical storm	
		Extra-tropical cyclone (winter storm)	
		Local / connective storm	Thunderstorm/ lightening
			Snowstorm / blizzard
			Sandstorm / dust storm
			Generic (severe) storm
			Tornado
			Orographic storm (strong winds)

beetles invasion in Canada may reach $2 billion over a 30-year period (NRC 2014). Global infestation can have a much higher economic damage as shown in Table 9; according to one estimate the global damage inflicted by invasions can run up to $1.4 trillion per year, making it much costlier than the annual global cost of natural disasters (Ricciardi et al. 2011). Overall, viral and bacterial infectious diseases compromise the highest proportion of biological disasters. Viral infectious diseases affect most people, while bacterial infectious diseases cause highest mortality.

2.5 Geophysical

Geophysical disasters originate from solid earth and include earthquakes, volcanoes and dry mass movement, which lead to tsunami, rockfall, avalanche, landslide and subsidence (EM-DAT 2017, Table 10).

Geophysical disasters are the rarest of all classes of disasters; however, they affect and cause the most injuries and deaths (Fig. 2). Earthquakes occur 77.5% of all geophysical disasters making it the most common event, affecting and injuring most people. Earthquakes can also lead to tsunamis, and even though they represent only 4.5% of geophysical disasters, they cause almost as much damage as earthquakes themselves, making them disproportionally devastating events (Table 11).

Geophysical disasters pose similar health risks associated with other disasters, due to population displacement caused by property damage during earthquakes and tsunami, as well as damaged water-treatment and sewage facilities. Floret et al. (2006) inferred based on their research of over 600 disasters between the years of 1985 and 2004, there were only three recorded outbreak cases, which were: measles outbreak after the eruption of Pinatubo in Philippines, coccidioidomycosis after an earthquake in California and a malaria outbreak in Costa Rica after an earthquake and heavy rainfall. Even though epidemics are rare following geophysical disasters, there are other health risks that first responders are subjected to that must be looked into.

Table 5 Data gathered from EM-DAT based on hydrological events from years 2000 to 2015

Type	Occurrence	Deaths	Affected	Injured	Homeless	Total damage	% of total
Meteorological	1993	352,114	634,424,869	2,280,316	6,462,869	799,479,765	
Extreme temperature							
Cold wave	191	10,677	9,068,532	1,833,672	233,000	5,195,134	9.58
Heat wave	104	146,679	112,842	115,843		13,382,859	5.22
Severe winter conditions	63	3569	81,747,153	16,029	5247	23,960,200	3.16
Storm	214	2201	22,436,694	12,475	175,569	11,533,431	10.7
Convective storm	515	6098	148,126,467	124,173	817,470	185,974,804	25.8
Extra-tropical storm	82	268	526,440	294	1600	31,564,600	4.11
Tropical cyclone	824	182,622	372,406,741	177,830	5,229,983	587,868,737	41.3

Retrieved from: http://www.emdat.be/advanced_search/index.html

Table 6 Table adapted from information available on EM-DAT

Class	Type	Sub-type	Sub-sub type
Climatological *(events caused by long-lived, meso to macro scale processes in the spectrum from intra-seasonal to multi-decadal climate variability)*	Extreme temperature	Heat wave	
		Cold wave	Frost
		Extreme winter conditions	Snow pressure
			Icing
			Freecing rain debris avalanche
		Drought	
		Wild fire	Forest fire
			Land fires (grass, scrub, bush, etc)

Retrieved from: http://www.emdat.be/frequently-asked-questions

Table 7 Data gathered from EM-DAT website based on hydrological events from years 2000 to 2015

Type	Occurrence	Deaths	Affected	Injured	Homeless	Total damage	% of total
Climatological	467	22,123	986,259,050	5486	59,272	113,194,494	
Drought (other)	1	0	2,400,000	0	0	0	0.21
Drought	278	21,182	981,218,350			80,175,807	59.5
Wildfire	17	104	59,060	83	9570	3,351,000	3.64
Forest fire	133	430	1,847,123	1289	34,495	20,787,867	28.5
Land fire	38	407	734,517	4114	15,207	8,879,820	8.14

Retrieved from: http://www.emdat.be/advanced_search/index.html

Table 8 Table adapted from information available on EM-DAT website

Class	Type	Sub-type
Biological *(disasters caused by the exposure of living organisms to germs and toxic substances)*	Epidemic	Viral infectious diseases
		Bacterial infectious diseases
		Parasitic infections
		Fungal infections
		Prion infections
	Insect infestation	Grasshopper
		Locust
		Worms
	Animal stampede	

Retrieved from: http://www.emdat.be/frequently-asked-questions

Table 9 Data gathered from EM-DAT website based on hydrological events from years 2000 to 2015

Type	Occurrence	Deaths	Affected	Injured	Homeless	Total damage	% of total
Biological	772	90,197	10,034,832	491,794	–	120,000	
Animal accident	1	12	5				0.13
Epidemic	79	6216	184,135	100	0	0	10.2
Bacterial infectious diseases	366	51,441	2,171,522	339,675	0	0	47.4
Parasitic infectious diseases	15	643	1,138,076	0	0	0	1.94
Viral infectious diseases	292	31,885	3,741,094	152,019	0	0	37.8
Insect infestation	3	0	2800,000	0	0	0	0.39
Locust	16	0	0	0	0	120,000	2.07

Retrieved from: http://www.emdat.be/advanced_search/index.html

Table 10 Table adapted from information available on EM-DAT website

Class	Type	Sub-type	Sub-sub type
Geophysical *(events originating from solid earth)*	Earthquake	Ground shaking tsunami	
	Volcano	Volcanic eruption	
	Mass movement (dry)	Rockfall	
		Avalanche	Snow
			Debris
		Landslide	Mudslide
			Lahar – Debris flow
		Subsidence	Sudden subsidence
			Long-lasting subsidence

Retrieved from: http://www.emdat.be/frequently-asked-questions

3 First Responders – Who They Are and How Are They Different

Natural disasters attract a lot of attention and can urge people to help in whatever capacity they can contribute to powerful outcomes. Some people might donate money or belongings, while others would want to volunteer their time and expertise. These volunteers might hail from various backgrounds with varying driving factors.

Question around whether they have appropriate training and education and/or any association with established organizations are imperative in this field. Some of the people who feel motivated to help may be untrained or may not be associated with an organization established in the impact region.

Before the 2004 Indian Ocean Tsunami there were only a handful of Non-Governmental Organizations (NGOs) present in the Province of Aceh, Indonesia; however, following the disaster the number swelled to approximately 300 (Canny 2005). Such rapid influx of volunteers does not always lead to positive effects. It is absolutely vital that first responders arrive at the site of events not only prepared physically and mentally for the deployment, but also healthy enough not to endanger the vulnerable population. Occasionally, first responders can become victims themselves and use resources originally allocated to the affected population. When first responders become victims of a natural disaster, not only are they using up medicinal and care resources that were delivered for the affected population, but they also decrease the number of available staff. It is from this standpoint, that first responders always have to arrive prepared with full knowledge of their health risks.

3.1 Impacted First Responders

The first group of first responder arises at the site of the emergency. These are people who were not critically harmed themselves but are capable of providing assistance within their immediate surrounding. These responders will always be on site first and are unlikely to have any prior experience. They pose danger due to their inability to identify safety and health risks; however can save the most lives due to their immediate availability. Ninety four percent of survival following an earthquake are found in the first 2 weeks after the event and the number climbs steeply with each passing day making delays in search and rescue efforts a strong factor in the total mortality of the disaster (Zhang et al. 2012). It is important to relieve these individuals as fast as possible to allow them to attend to their personal needs, which can be health or livelihood related. Current strategies for emergency recovery see individuals gaining emergency employment if their primary source of income was jeopardized during the disaster. Resilient strategies during recovery will allow individuals to gain necessary experience to provide better response during future disasters improving outcomes of their community. Impacted first responders will never have the same level of expertise as trained first responders. Protocols and recommendations are in place regarding first responders who have completed adequate training in order to be deemed prepared for an international deployment within an organization that is already established at the site of event or was officially invited to participate in the response and recovery phases of the disaster management.

Table 11 Data gathered from EM-DAT website based on geophysical events from years 2000 to 2015

Type	Occurrence	Deaths	Affected	Injured	Homeless	Total damage	% of total
Geophysical	547	714,466	100,435,540	1,440,279	12,609,185	493,655,203	
Earthquake	2	78	0	171	14,555	0	0.37
Ground movement	423	465,506	95,153,763	1,389,517	11,443,115	271,199,794	77.3
Tsunami	23	247,860	2,486,140	49,358	1,033,559	221,379,540	4.2
Mass movement dry	1	10	0	0	0	0	0.18
Avalanche	1	16	0	0	0	0	0.18
Landslide	7	220	2037	20	1331	8000	1.28
Rockfall	2	111	0	72	625	0	0.37
Volcanic activity	3	63	190,587	69	0	0	0.55
Ash fall	83	602	1800,513	1072	116,000	1,067,869	15.2
Lava flow	2	0	802,500	0	0	0	0.37

Retrieved from: http://www.emdat.be/advanced_search/index.html

3.2 Local First Responders

First professional response to any emergency arrives from the local agencies prior to or concurrently with a call for international assistance going out. Local teams will have professional training and preparedness. However, one should be mindful of cases where local first responders' family members might be impacted causing their attention, distress, and distracting from providing relief efforts. A number of other barriers that could prevent responders from reaching the site include damaged road to allow access and dependent care when both spouses are first responders.

Local responders have local knowledge of customs and threats. They are usually able to get to the location fast and start life saving measures quickly. Their preparedness level depends on the resources available to their organization. If the organization lacked good decision making and adequate preparedness, they might not have access to the latest equipment that would assist in rescue operations. Health risk factors presented by natural disaster will affect local first responders but they should be well aware of hazards prevalent in their communities.

3.3 National First Responders

National responders generally have access to the best equipment and training programs that the country can offer. Unfortunately, those opportunities might be strained based on the economic capacity of the country as well as the frequency with which these resources are utilized. The political situation in the country might also influence success and acceptance of the national responders in affected communities. There might be a large number of hazards present for national responders to prepare for, and they should be encouraged from early stages of training to consider health risks associated with hazards of highest frequency for their country.

3.4 International First Responders

International responders work within a scope in which they are allowed to function. They cannot arrive in the country without an invitation, and their equipment has to pass customs prior to being released. These can be contributing factors to the delay of a rescue mission's onset and negatively impact survival rate during the unfolding of the disaster. International responders can vary in their preparedness level from being associated with an army to being a specialist who volunteers their time during disasters. For example, Global Medic, a registered Canadian charity organization, specializes in providing rapid and short term assistance comprised of clean water, medical assistance, shelter, and search & rescue. It is more likely that professionally trained responders will have adequate preparedness level prior to the deployment but even within those organizations it is crucial to establish health risk program that will enable better preparedness based on the geo-political location of the disasters. This requirement becomes crucial for volunteer organizations where responders might not have been deployed in years or generally do not go through adequate level of training.

First responders need to be reminded that part of their preparedness needs to include personal preparedness – for example, ensuring that their medical needs are met, they have appropriate amount of personally required medication as well as any other medication they foresee requiring during their deployment.

4 Health Risks Faced by First Responders

There are many types of natural disasters and there are many types of health effects that they can produce. In general, developing countries are more affected by health outbreaks due to pre-impact lack of resources and infrastructure (Watson et al. 2007; Waring and Brown 2005), while NATECH events affect industrialized countries to a greater extent because of high population density living in close proximity to industrial sites (Young et al. 2004). It is also noteworthy here that accidents such as the Union Carbide gas leak incident in Bhopal, India in 1985 occurred due to multinational companies operating in poor nations where low-cost labour is willing to work in high risk industries. Additionally, accidents such as the BP Deep Water Horizon in 2010 in the Gulf of Mexico affected the region damaging flora and fauna to an unprecedented magnitude.

Natural disasters can cause a high mortality rate, and there is a common myth that dead bodies pose a health risk. However, it is only the case when a pathogen spread, such as cholera or hemorrhagic fever occurs by direct contact with infected body fluids (Watson et al. 2007). The greatest threat of epidemics after a natural disaster is often due to overcrowding among the displaced individuals, poor ventilation, poor health status and lack of immunization prior to the disaster. Furthermore, lack of clean water and sanitation, which leads to either respiratory or gastrointestinal diseases can turn into a widespread health risk (Watson et al. 2007; Jobe 2011; Birn et al. 2009). In fact, outbreaks are more common in conflict-stricken areas rather than in disaster affected areas. However, depending on the geographical location of the disaster, the same event can lead to different health risks. For example, a flood occurring in the developed world can cause an industrial spill or an industrial waste tailing pond to fail, potentially leading to an exposure to hazardous materials for communities in the region. If the same magnitude flood occurs in the developing or poor nations, the risk of an increased rate of gastrointestinal epidemics due to suboptimal sanitation and hygiene, as well as fecal contamination of drinking water is more likely to occur (Watson et al. 2007). Health risk of first responders is thus dependent on the class of natural disaster as well as the geographical location of the event.

Health effects can be classified into waterborne, crowding, vector-borne, wound and other diseases as summarized in Appendix A. Waterborne diseases occur due to contamination of drinking water, poor sanitation and crowded shelters (Watson et al. 2007; Waring and Brown 2005). Cases are reported following flooding or other related displacements. Crowding conditions, which are common if population are displaced by natural disasters, occur due to a high number of people who are potentially malnourished living in close proximity to each other with poor ventilation. Wound related diseases occur when wounds become contaminated in people who have not been immunized in the last 10 years. People who are at risk of being affected are both victims and first responders if they are working with natural disaster debris. Other diseases in this case include coccidiomycosis, which is caused by a fungus found in soil when individuals are exposed to airborne dust. Finally, vector-borne diseases occur when new breeding sites for vectors (mosquitos) are created by standing water as well as due to disaster related displacement individuals changing their living habits, such as sleeping outside thus increasing their risk of being infected. Onset of vector-borne diseases usually occurs up to 8 weeks following a disaster (Waring and Brown 2005). An example of a NATECH event that can increase the risk of epidemics is power failure which can lead to failure of water treatment and supply facilities, thus increasing the risk of waterborne diseases and disrupt functioning of health facilities and vaccine preservation (WHO 2006). Health risk factors are incorporated into Table 12 based on a report compiled by the WHO following the 2004 Indian Ocean Tsunami, highlighting the need for proper hygiene and living conditions for the displaced population (WHO 2005). First responders working with the displaced population must have personal protection equipment as well as pharmaceuticals to protect themselves against diseases they will be exposed to during their deployment.

The Ebola outbreak in western Africa got worse due to prevalent flooding situation in Sierra Leone (Dumbuya and Nirupama 2017). Since July 2014, CDC (CDC 2015) had sent staff on almost 3000 deployments to support the Ebola response in West Africa, the United States, and elsewhere around the world. Responders filled a variety of roles, from disease detectives, to laboratorians, to logisticians, to health communication experts.

NATECH events rarely lead to epidemics, however, they can lead to direct releases such as chloride or ammonia following droughts, or indirect release such as agrochemicals washed into floodwaters. They can cause respiratory problems as well as expose population carcinogens and poisonous materials (Young et al. 2004).

Classification of health risks following natural disasters will aid in determining health risks of first responders during their deployment by allowing them to estimate type of pathogens they can be exposed to, based on the number of days lapsed following a natural disaster. Each class of a natural disaster is associated with different health risks, and each phase of a natural disaster has a different impact on human health and therefore requires different approaches for response. Natural disasters can be divided into pre-impact, impact, and post-impact phases (Binder and Sanderson 1987; Fig. 3).

During the pre-impact phase, public health interventions have the most impact on saving lives. For example, most deaths following earthquakes are due to structure collapses, as a result city officials can decrease morbidity (injuries and suffering) of

Table 12 Health hazards and their harm to human health

Health hazard	Health hazard example	Associated harm	Comments
Overcrowding	Inadequate shelter	Crowding diseases	Overcrowding is exacerbated by poor immunization
Food insecurity	Malnutrition	Acute respiratory infections	
		Vitamin deficiency and associated diseases	
Poor quality or quantity of water	Poor hygiene	Waterborne diseases	
	Poor washing facilities	Wound related diseases	
	Poor sanitation		
Standing water	Increased exposure to mosquitoes	Vector-borne diseases	Population movement and interruption of vector control measures increases risk of vector-borne diseases
	Increased number of breeding sites		
Inadequate health care services	Disruption of basic services		Waterborne diseases
			Crowding diseases
Debris	Open wound or lacerations	Wound related diseases	
	Trauma and injury	Infections	
NATECH	Toxin release	Exposure to harmful toxins	
Infrastructure damage	Electricity	Electric shock	
		Burns	
Power outage	Improper use of indoor generators, heaters or cooking devices	Carbon monoxide poisoning	

Information compiled from WHO (2005), Young et al. (2004) and Watson et al. (2007)

the population by enforcing building codes appropriate for the earthquake risk of the area. During this phase of a natural disaster, first responders are not directly impacted. Once an imminent hazard is recognized, such as an early warning for a major hurricane; first responders are provided with a guideline as to where they might potentially be deployed and what health risks they need to be prepared for. This phase is characterised by mitigation and preparedness actions of emergency management.

In the impact phase, health is affected by the release of energy of the event; be it either a volcanic eruption or a tornado. In this phase, vulnerable population will have the greatest suffering. During the 2011 Japanese tsunami, fishermen living in coastal communities were the first ones to suffer the impact of the hazard. The failure of the Fukushima nuclear power plant released harmful radiation into the atmosphere, water courses, and the soil causing severe health risk to the surviving

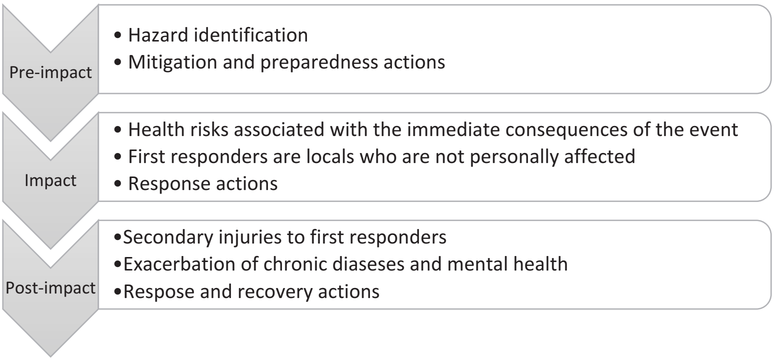

Fig. 3 Natural disaster phases and factors affecting population health (Adapted from Binder and Sanderson 1987)

population as well as the first responders. During the impact phase of the 2004 Indian Ocean tsunami, coastal communities not only sustain a high mortality, but also economic impact by losing their boats which served as sources of income (Keys et al. 2006). In this phase, first responders will generally be local survivors of the disaster.

Finally, the post-impact phase includes secondary injuries usually to local, national and international first responders as they perform relief operations post a natural disaster.

Floods, being the most frequent natural hazards, can serve as an example of how to analyze disasters and health risks that can impact first responders. Causes of morbidity and mortality following a flood can by due to direct or indirect impacts. Direct impact causes drowning (usually flash floods, coastal floods, or hurricane landfall), fatal injuries during evacuation and clean up, injuries (which are small, such as lacerations caused by the debris cleanup), and electrical shock (WHO 2014). Communicable disease outbreaks are rare after floods but can occur after drinking contaminated water or from an increase in the amount of standing water which leads to water-borne (typhoid fever, cholera, leptospirosis, and hepatitis A) and vector-borne (malaria, dengue and dengue haemorrhagic fever, yellow fever, and West Nile Fever) diseases. Indirect causes include impact on the health and critical infrastructure such as water and power supply (can lead to the consumption of spoiled food), as well as disruption in food supply which can cause food shortages increasing risk of malnutrition, weakening the immune system for immediate and future disasters. A summary of flood related health effects is presented in Table 13.

Hazardous materials can be released unintentionally if standing water is sprayed with pesticides to decrease a risk of vector-borne diseases or due to water becoming contaminated with chemicals that are stored in private homes or industrial sites, particularly if underground oil or gasoline pipelines are ruptured. Damaged sewage systems can cause water overflow or exposure of buried waste which might cause waste water contamination (Young et al. 2004). Hurricane Floyd in 1987 caused flooding of waste lagoon and municipal waste-treatment plants in North Carolina

Table 13 Table is adapted from a report on health impacts of flood in Europe and combined with information presented in Table 1 (Guha-Sapir et al. 2010)

Direct impact	Health Hazard	Example
Mortality	Drowning	
	Injury	Injuries during evacuation and clean up
	Exposure to the environment	Hypothermia
	Debris	Refer to Table 1
	Trauma	
	Vehicle-related deaths	
	Mud and water rushing in on campsites	
Morbidity	Injury	Contusions, lacerations, abrasions, cuts, bruises, sprains, strains and puncture wounds
Respiratory infections		Colds, coughs, flue, headaches, acute asthma, allergies to moulds
Other health hazards		
Health care services	Refer to Table 1	
Infrastructure damage		
Poor water quality		
Standing water infections		

releasing hundreds of thousands of gallons of biological waste into waterways. Carbon monoxide (CO) poisoning was added as a potential flood-related hazard due to an increasing number of reported cases in the last two decades (Daley et al. 2001). The danger is associated with using generator, power washers and others gasoline burning engines indoors where dangerous levels of CO can be reached within minutes. Providing education on safety and ensuring proper functionality of the equipment is imperative to mitigate this hazard.

There is a distinct possibility that first responders to floods might become primary victims since floods can develop rapidly; however, it is much more likely that responders will arrive in the post-impact phase. Their exposure to health risks will depend upon the time of their arrival. Their biggest risks would include lacerations and wound exposure to local bacteria and fungus during the search and rescue phase, diarrheal and respiratory diseases from the victims, and exposure to any potential hazardous materials released during or following the disaster. Pre-deployment awareness of potential endemic diseases and local hazards would help devise preventive strategies and reduce risks to responders.

This information is useful when put into the context of the type of natural disasters in which these hazards occur. In order to ensure first responders preparedness for the deployment, similar analysis should be performed for each class of disasters that the organization responds to and create preparedness checklists for their staff to complete prior to the deployment.

As discussed earlier, natural disasters differ in their triggering event, their characteristics, and effects they cause on the impacted communities. It is estimated that a nation in Asia is 28.5% more likely to experience a disaster in any given year than in Africa (Kahn 2005). Health hazards associated with natural disasters are just as diverse. Some of the primary health hazards were presented in Table 1 and are used throughout the text. Research presented in this paper identified additional health hazards that are presented in Table 14.

It is important to remember that hydrological disasters are the most frequently occurring disasters, and among them floods represent the biggest threat. It is of no surprise then that floods are a common secondary disaster to many others events as shown in Table 15.

Table 14 Updated table on health hazards associated with natural disasters based on information presented in the text

Health hazard	Health hazard example	Associated harm	Comments
Overcrowding	Inadequate shelter	Crowding diseases	Overcrowding is exacerbated by poor immunization
Food insecurity	Malnutrition	Acute respiratory infections	
		Vitamin deficiency and associated diseases	
Poor quality or quantity of water	Poor hygiene	Waterborne diseases	
	Poor washing facilities	Wound related diseases	
	Poor sanitation		
Standing water	Increased exposure to mosquitoes Increased number of breeding sites	Vector-borne diseases	Population movement and interruption of vector control measures increases risk of vector-borne diseases
Inadequate health care services	Disruption of basic services		Waterborne diseases Crowding diseases
Debris	Open wound or lacerations	Wound related diseases	
	Trauma and injury	Infections	
NATECH	Toxin release	Exposure to harmful toxins	
Infrastructure damage	Electricity	Electric shock	
		Burns	

(continued)

Table 14 (continued)

<table>
<tr><th>Health hazard</th><th>Health hazard example</th><th>Associated harm</th><th>Comments</th></tr>
<tr><td>Power outage</td><td>Improper use of indoor generators or heaters</td><td>Carbon monoxide poisoning</td><td></td></tr>
<tr><td rowspan="3">Lightening</td><td rowspan="3">Delivery of electrical current</td><td>Fire</td><td rowspan="3"></td></tr>
<tr><td>Burns</td></tr>
<tr><td>Death</td></tr>
<tr><td rowspan="2">Hail</td><td rowspan="2">Fast falling large icicles</td><td>Properly damaged</td><td rowspan="2"></td></tr>
<tr><td>Killed livestock</td></tr>
<tr><td rowspan="6">Wind</td><td>Properly damage</td><td>Injury from the projectiles</td><td rowspan="6"></td></tr>
<tr><td>Projectiles</td><td>Trauma during clean up</td></tr>
<tr><td>Knocked down trees</td><td>Electrical burns</td></tr>
<tr><td>Knocked down power lines</td><td>Power outage (see above)</td></tr>
<tr><td>Knocked down mobile homes</td><td rowspan="2">Debris (see above)</td></tr>
<tr><td>Unsafe traveling conditions</td></tr>
<tr><td rowspan="4">Snow</td><td>Building collapse</td><td>Debris (see above)</td><td rowspan="4"></td></tr>
<tr><td>Downed trees/ power lines (see above)</td><td>Motor-vehicle accidents</td></tr>
<tr><td>Isolation of homes in rural communities</td><td rowspan="2"></td></tr>
<tr><td>Poor driving conditions</td></tr>
<tr><td>Cold</td><td>Cold temperatures</td><td>Respiratory, cardiovascular, peripheral circulation, musculosketetal</td><td>Cerebrovascular accidents and coronary heart disease could be lethal</td></tr>
<tr><td rowspan="3">Dust</td><td rowspan="3">Elevated soil or sandstorm</td><td>Poor visibility</td><td rowspan="3"></td></tr>
<tr><td>Respiratory diseases</td></tr>
<tr><td>Acute respiratory infections</td></tr>
<tr><td rowspan="6">Heat stress</td><td rowspan="6">Inability to lower internal body temperature</td><td>Skin eruption</td><td rowspan="6"></td></tr>
<tr><td>Heat fatigue</td></tr>
<tr><td>Heat cramps</td></tr>
<tr><td>Heat syncope</td></tr>
<tr><td>Heat exhaustion</td></tr>
<tr><td>Heat stroke</td></tr>
</table>

Table 15 Natural disasters that occur alongside other disasters

Flood	Mass movement	Wildfire	Tornado	Strong winds	Tsunami
Blizzard followed by a tempearture increase	Volcanic eruption	Heatwave	Thunderstorm	Winter storm	Volcanic eruption
Tropical cyclone	Earthquake	Drought	Hurricane	Hurricane	Earthquake
Tsunami	Melting snow	Lightening		Blizzard	Meteor impact
Local storms	Rain downpoor				Underwater explosion
	Hurricane				
	Tsunami				

5 Case Studies

5.1 Japan – The 2011 Tohoku Earthquake and Tsunami

On March 11, 2011 at 2:46 pm a 9.0 magnitude earthquake took place 370 kilometers northeast of Tokyo at a depth of 24.5 kilometres (CNN 2013). The earthquake generated a tsunami that took an hour for up to 40 meter high waves to hit the coastline damaging nuclear reactors in the Fukushima nuclear plan, sweeping away vehicles, causing building (including hospitals) to collapse, and damaging several roads and highways (NOAA 2017; The Atlantic 2017). In the affected area, almost 80% of hospitals and a third of medical/dental clinics experienced various levels of damage, requiring patient evacuation and relocation (Saito and Kunimitsu 2011). While, more than 300 patients had to be evacuated from hospitals isolated by the tsunami, it is estimated that up to 1700 people who were ordered to "stay indoors" were evacuated from hospitals and nursing homes within a 20 km to 30 km radius from the damaged reactors (Saito and Kunimitsu 2011).

The earthquake and tsunami caused $220 billion damage in Japan and resulted in a nuclear disaster with an International Atomic Energy Agency (IAEA) rating of 7 at the Fukushima Daiichi Nuclear Power station. The tsunami also caused $30 million damage in Hawaii; $55 million damage to marine facilities in California; and $6 million in losses to the fishing industry in Tongoy, Chile over 16,000 km from the source. This was the first time observational evidence from satellites linked a tsunami to ice-shelf calving in Antarctica (NOAA 2017). The power cut off and the failure of the backup generators left at least six million homes without electricity and a million without water. Prolonged blackouts, water outages and fuel shortages also affected hospitals in the surrounding areas putting additional levels of stress on the facility. At the time of emergency declaration radiation levels were more than eight times the normal near the plant's main gate (Saito and Kunimitsu 2011; CNN 2013; The Atlantic 2017). Within 2 days of the disaster, a total evacuation numbers reached 185,000 and 50,000 Japan Self-Defense Forces personnel, 190 aircraft and 25 ships were deployed

Fig. 4 Overview of the Fukushima Daiichi Nuclear Power Plant impact area (NAIIC 2012)

to assist with rescue efforts. Due to escalating harmful radiation concern, an evacuation affecting almost 100 thousand people was declared. It is estimated that there were a total of 15,890 confirmed deaths and 2590 missing and presumed deaths; and 6152 injuries in 12 Japanese prefectures. (NOAA 2017) (Fig. 4).

While a lot of health and safety risks came from floodwaters, downed power lines, wet electrical outlets, interrupted gas lines and debris (CDC 2011), major concerns arose from the dangerous levels of radiation in the region. The government of Japan declared that the first priority after the incident was search and rescue working closely with local governments to evacuate residents and provide first aid and relief to victims, even though understanding of their medical needs was not easy (Saito and Kunimitsu 2011). Overall, hundreds of responders arrived in Japan to assist with the disasters as offers arrived from 116 countries and 28 international organizations. Japan specially requested assistance from teams from Australia, New Zealand, South Korea, and the United States, based on the need assessment (ABC 2011; WHO 2013a). The IAEA rating 7 incident amounted to a widespread release of radioactive material with severe health and environmental effects calling for a planned and extended counter measure (CNN 2011). Packs of potassium iodide tablets were made available by the 374th Medical Support Squadron at Yokota medical hub (Fig. 5).

During this time a shipment of rice from some farms northwest of the Fukushima Daiichii nuclear power plant was discontinued due to higher-than-allowed levels of radioactive cesium. At least 45 metric tons of radioactive waters were leaked from the nuclear facility contaminating the region and the Pacific Ocean. Studies by the World Health Organization estimated that the lifetime risk of developing leukaemia may have increased by about 7%; breast cancer by 6.5%; and 4% for all solid cancers. A 70% increase in thyroid cancer in females exposed as infants (WHO 2013a) is very concerning. National Institute of Health concurrently conducted their own studies and found an increased rate of asthma among girls (Talesnik 2015). To ensure the safety of responders and the residents, the 374th Aerospace Medicine Squadron bio-environmental flight scan was routinely conducted (Fig. 6).

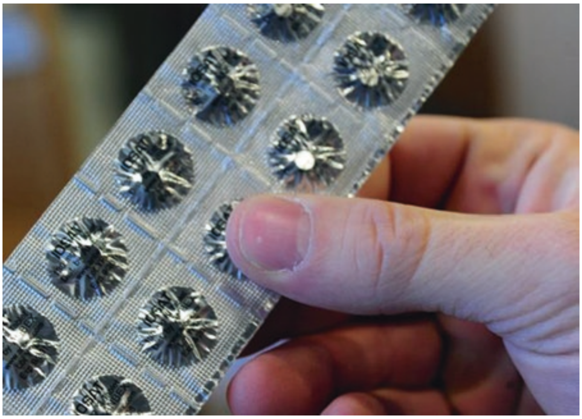

Fig. 5 YOKOTA AIR BASE, Japan – Tech. Sgt. Greg Murray inspects packs of potassium iodide tablets at the medical logistics flight warehouse, Yokota Air Base, Japan, April 4, 2011 (By U.S. Air Force photo/Senior Airman Michael J. Veloz [Public domain], via Wikimedia Commons)

Fig. 6 Two members of the 374th Aerospace Medicine Squadron bio-environmental flight scan a returned C-130H Hercules for radiation at Yokota Air Base, Japan, March 25, 2011 (U.S. Air Force photo/Staff Sgt. Samuel Morse)

In 2012, the National Diet of Japan published the official report of the Fukushima nuclear accident independent investigation commission (NAIICS 2012) concluding that the nuclear crisis was a "manmade" disaster – the result of collusion between the government, the regulators and TEPCO, and the lack of governance by said parties. They effectively betrayed the nation's right to be safe from nuclear accidents. It was further complicated by the fact that the Basic Disaster Management Plan for Japan included plans for four natural disasters and eight accidental disasters but not combined ones. Responders possessed very limited knowledge of radiation protection and expected resources, such as electricity and lines of communication in the off-site centres, were not available (Saito and Kunimitsu 2011). Disasters, by definition overwhelm available resources and are often seen as unique events in their development; however, due to high level of potential health risk to responders it is crucial they possess necessary knowledge and resources to perform their duties safely and effectively.

5.2 The Philippines – The 2013 Typhoon Haiyan

On November 8th, 2013 Super Typhoon Haiyan, or Yolanda as it is locally known, went through the central Philippines. It was the strongest storm to ever make landfall with sustained wind speeds of 314 km/hour and wind gusts of up to 378 km/hour (Fig. 7). On the Saffir-Simpson scale, it was a Category 5 storm that generated sea surge of up to five meter and affected 4.2 million people, across 36 provinces in the Philippines (Mercy Corps 2013; US Marine Corps 2013). Total deaths are estimated to be 6340, and 2.5 million people in need of food (Mercy Corps, 2013, DEC, 2013). The World Health Organization classified this disaster as Category 3, the highest level, putting it on par with the 2004 Indian Ocean Tsunami and the 2010 Haiti Earthquake.

Fig. 7 Track map of Typhoon Haiyan. The points show the location of the storm at 6-h intervals. The colour represents the storm's maximum sustained wind speeds as classified in the Saffir–Simpson hurricane wind scale (By Meow [Public domain], via Wikimedia Commons)

Fig. 8 By Marines from Arlington, VA, United States (Haiyan Relief) [Public domain], via Wikimedia Commons

Humanitarian organizations in coordination with WHO worked tirelessly on providing water purification tablets, special diarrhoeal kits, and medicines and supplies to cover the basic health needs. The question was to manage the survivors due to the fear of an epidemic to erupt (Majumdar 2013). Four completely self-sufficient field hospitals from countries including Israel and Norway landed in the Philippines, but had to wait for hours for flights and boats to get them to the worst hit areas. Figure 8 shows US Marines helping survivors.

Infrastructure damage in the Haiyan path included downed power lines, lost communication, destroyed roads and many of the already vulnerable health facilities were left damaged or completely destroyed (WHO 2013d). This made it difficult to reach the affected people to provide relief. Part of the recovery processes included providing emergency employment to the victims who have lost income sources due to infrastructure damage (USAID 2014). As a result of the short-term employment program nearly 1500 km of roads and more than 1100 km of drainage canals were repaired and approximately 560 schools, 220 rural health care centres and more than 30 hospitals were restored (USAID 2014). These works were possible with the help of locals and long-term recovery personnel.

The WHO, in coordination with the Department of Health (DoH) of the Philippines, organized relief efforts for the survivors. They coordinated over 150 foreign medical teams and more than 500 tonnes of medical supplies and equipment that arrived in response (WHO 2013d). Of the local responders the DoH noted a total of 75 DoH team, 60 foreign teams, and 23 local health teams that were deployed to the affected areas. The government noted that the first responder, though, were victims themselves (DoH 2013).

Health needs arrived in waves, including the national and foreign teams treating injuries and attending to pregnant women and newborn children (WHO 2013b). During this time, the top five health events were acute respiratory infections, wounds, high blood pressure, fever, and animal bites (WHO 2013c). The second waves saw focus on disease outbreak prevention, including organization of mass immunisation of children against measles and polio, debris clean up and preventing the spread of diseases such as dengue and typhoid. Throughout these phases, the health of the responders was equally important, as well as the survivors. The DoH focused on watching tetanus, water-borne diseases, respiratory illness, childhood diseases and vector-borne diseases like leptospirosis, dengue and rabies to avert outbreaks and epidemics (DoH 2013). The third wave arrived within 3 months, focusing on non-communicable diseases such as heart attacks and diabetes as patients either lost their medication or were experiencing complications from the additional stress. Finally the fourth wave came within 6 months with an increase in mental health issues (WHO 2013b). It is noteworthy that within a year of the disaster, there were no major disease outbreaks in the affected areas while services such as reproductive health care, mental health provision and water quality testing became available (WHO 2013b).

Response measures saw an influx of many international responders who came in a setting of extreme devastation. They worked with limited medical resources, depending on the supply from international sources, making it imperative to be aware of their personal medical needs and have sufficient supplies with them to sustain in a high stress environment.

5.3 Haiti – The 2010 Earthquake

The magnitude 7.0 earthquake that occurred on January 12, 2010 (Fig. 9) killed over 150,000 people, affected about three million people, and destroyed 280,000 residential and commercial buildings. This Caribbean country is prone to natural disasters; they are regularly hit by tropic storms, floods, mudslides and powerful earthquakes. During the 2008 hurricane season, they were hit by four storms which claimed the lives of 800 people. They also suffered from dire flooding in 2002, 2003, 2006, and 2007 (Jones 2016). Continuing deforestation practices make matters worse for communities.

Haiti presents as an extreme example of natural disaster vulnerabilities based on its geomorphology as well as social and economic factors. The threat faced by the nation is not only due to the frequency of hazards but from the lack of their coping capacity. This leaves the country highly exposed and vulnerable to environmental hazards. In order to fully understand the impact of the 2010 Earthquake that struck Haiti, it is important to first understand conditions of Haiti prior to the event. Haiti had been occupied by Spain and France until the early nineteenth century. It became the first independent Caribbean state in 1825, but freedom came at the price of a payment of 150 million Francs. It took until 1947 for the debt to the former slave owners to be repaid. Since gaining independence, Haiti has been engulfed in chronic instability, dictatorship and natural disasters which left it as one of the poorest nations in the Americas. In 1994,

Fig. 9 Map of epicenter of 2010 Haiti Earthquake. By Haiti_map.png: CIA derivative work: The Weatherman (Haiti_map.png) [Public domain], via Wikimedia Commons

a newly elected Haiti government dismantled the military, which caused a lot of unrest via coups in the past, leaving the police as the only institution in charge of security (Goyet et al. 2011; Jones 2016). As a result, a UN peacekeeping mission was established in 2004 and has been helping stabilize the country since (BBC 2017).

Part of Haiti's extreme vulnerability stemmed from poor construction of the buildings, high occupational density of those dwellings, and severe damage to facilities with high occupancy such as schools, universities, and administrative buildings during disasters (Goyet et al. 2011). Haiti was ranked 163 out of 188 countries in 2014 in the UN Human Development index, which is a composite index measuring average achievement in three basic dimensions of human development—a long and healthy life, knowledge and a decent standard of living (UNDP 2014; Goyet et al. 2011; BBC 2017). On the World Risk Index, which is based on exposure to natural hazards, susceptibility, coping capacities, and adaptive capacities, Haiti ranks 21 (WRR 2016).

During the 2010 earthquake, the world responded with compassion and genuine concern for the people of Haiti. Humanitarian and disaster relief operations took over the landscape in an unprecedented way (Fig. 10). However, during the first 24 hours Haitians responded to the disaster by themselves, without a properly functioning healthcare system. About 60 International Urban Search and Rescue (USAR)

Fig. 10 Haitian citizens crowd a ship near a port in Haiti Jan. 16, after earthquake devastation left many homeless, injured and hungry. The aircraft carrier USS Carl Vinson (CVN 70) and Carrier Air Wing (CVW) 17 are conducting humanitarian and disaster relief. (By Mass Communication Specialist 2nd Class Candice Villarreal (http://www.navy.mil/view_image.asp?id=80042) [Public domain], via Wikimedia Commons)

teams responded from 30 nations with more than 1800 rescuers. Influx of such a large number of responders came at a price when the Nepalese UN troops introduced cholera and caused an outbreak that claimed about 10,000 lives in the country (BBC 2016). It was scientifically proven that the bacterial infection came from the UN base through leaking sewage pipes (BBC 2016). Unfortunately, once the bacteria entered the water source it was difficult to eliminate it, especially in a country with practically no effective sewage disposal system (BBC 2016; Chin et al. 2011); causing over 200,000 infections by October 2010. Based on data collected from Twitter, informally recorded cases on health cards, information on the extent of the outbreak was made available (WRR 2016).

Humanitarian response became easier to provide with targeted relief supplies needed in the right quantities at the right places and hence save numerous human lives (Fig. 11). Hundreds of displaced Haitians lived in make-shift homes outside Gheskio Field Hospital, located on Quisqueya University grounds, where International Medical Surgery Response Team technicians provided emergency medical attention to survivors. During this time, health workers had to also decide between caring for their own families and providing emergency care in their own neighborhoods. Disaster Medical Assistance Team members provided medical care to search and rescue personnel recovering victims from the ruble (Fig. 12). The recovery efforts were fraught with hazards including crushing injuries, infectious diseases, and inhalation hazards.

Since the devastating 2010 earthquake, Haiti has seen a number of other natural disasters, including an earthquake in 2016 and Hurricane Matthew in the same year.

Fig. 11 Hannah McDowell, an aid worker with God's Missionary Church in Penn's Creek, Pa., administers medicine to a Haitian child in Leogane, Haiti, Jan. 24, 2010. U.S. Marines flew into the area to establish a new humanitarian aid receiving area for Haitian earthquake victims at a missionary compound. By Cpl. Bobbie A. Curtis, USMC [Public domain], via Wikimedia Commons

Fig. 12 Tennessee-1 Disaster Medical Assistance Team member provides medical care to search and rescue personnel recovering victims from the ruble (By National Institute for Occupational Safety and Health (http://www.flickr.com/photos/niosh/8743414931/) [Public domain], via Wikimedia Commons)

While Haiti is struggling to rebuild the country from the last impact, they do not have the capacity to do so in a sustainable and safe manner, and that role could potentially fall on the international community. As seen in the previous example, first responders arriving to a site of the same disaster can find themselves facing very different challenges and threats to their own health. Haiti has struggled with stabilizing its own economy prior to the impact and will continue to do so for years to come.

6 Concluding Remarks

This chapter compiles a comprehensive list of health hazards associated with natural disasters to provide a practical reference to future responders. International organizations responding to disasters provide much needed assistance to local response teams; at the same time their presence can contribute to chaos and lack of coordination on the ground depending on the country and location of the event. A lot more should go into the risk assessment than merely knowing their direct threats such as type of disaster to which they are responding. They have to consider the historical context and the political state of the country, as well as their vulnerability, to ensure they would be an asset to the response and recovery measures and not a liability by taking up limited resources in case they need medication or treatment themselves.

It would be beneficial for first responders to familiarise themselves with health hazards associated with each disaster presented in the first row of Table 13, since it is likely their response will involve one of these events. Similarly, while there may be unique health effects for some events, there will be a lot of overlap; therefore, organizations should consider an “All-Hazards Planning” approach when preparing their teams for deployment.

There are few disasters in which first responders might arrive during the impact stage, such as a heat wave, drought or a winter storm. However, most of the time internationally deployed first responders arrive in the post-impact stage. The majority of natural disasters are associated with some level of property damage and population displacement, leading to unsafe water supply and potential bacterial outbreaks. It is therefore crucial to ensure that first responder’s immunizations are up-to-date, that personal protective gear is available, and that the responders are adequately trained in its usage to ensure that donning and doffing does not result in contamination. First responders should also be familiar with the challenges and limitations of working in the gear for prolonged time period such as fatigue, dehydration, et cetera to decrease the risk of being unable to work during the deployment. Having the necessary dosage and amount of mediation available to meet personal needs will alleviate potential strain on the limited local resources.

NATECH events present a particular secondary complication. Developed countries are at a higher risk of NATECH events because of the close proximity of industrial sites to communities to areas with high population density. Identifying locations of these sites prior to deployment would decrease the risk of toxic exposure by allowing first responders to take appropriate preparedness and mitigation measures. Japan’s 2011 tsunami and nuclear meltdown is an extremely tragic example that caused radiation to spread into the water, soil, and the environment. To this day, radiation related cancer cases are being reported and much of the population has not been able to return to their land. Some farmers brought in soil from other regions to start their greenhouses in order to claim their livelihood back.

Pre-deployment health of first responders is also of importance since disasters such as wildfires and volcanic eruption can exacerbate pre-existing conditions. Organizations might opt to not deploy vulnerable responders to ensure their continual health, or deploy along with sufficient mediations to decrease the strain on local medical service in case of adverse health impacts during the deployment. First responders should be in their most optimal health pre-deployment since it is difficult to exactly predict all of the health risks they will face, and the extent to which these risks will affect them.

Appendix A

Potential health affects following a natural disaster

Type	Sup-type	Symptoms	Transmission	Comments	Source
Waterborne Onset: 3–5 days Health promotion: Sanitation Water purification Personal hygiene Immunization Health surveillance	*Vibrio cholera* – Cholera	Diarrhea, vomiting	Contaminated drinking water or food, fecal/oral	Incubation period: 2 h to 5 days	Watson et al. (2007) and Waring and Brown 2005
	Escherichia coli				Watson et al. (2007)
	Hepatitis A	Jaundice, abdominal pain, nausea, diarrhea, fever, fatigue and loss of appetite	Fecal/oral, contaminated water and food	Most children develop immunity Pregnant women fatality can reach 25% Incubation period is 15–50 days	Watson et al. (2007) and Waring and Brown (2005)
	Hepatitis E			Incubation period is 15–50 days	Watson et al. (2007) and Waring and Brown (2005)
	Leptospira – Leptospirosis	Sudden onset fever, headaches, chills, vomiting, severe myalgia	Fecal/oral, contaminated drinking water by rodents urine that comes in contact with skin, mucous membranes with water, damp soil or vegetation or mud via flooding facilities	Incubation period: 2–28 days	Watson et al. (2007) and Waring and Brown (2005)
	Shigella dysenteriae – Bacillary dysentery	Malaise, fever, vomiting, blood and mucuos in stool	Fecal/oral, contaminated food or water	Incubation period of 12–96 hours	Waring and Brown (2005)
	Salmonella typhi – Typhoid fever	Sustained fever, headache, constipation	Fecal/oral, contained water or food	Incubation period 3–14 days	Watson et al. (2007) andWaring and Brown (2005)

(continued)

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Type	Sup-type	Symptoms	Transmission	Comments	Source
Crowding diseases Onset: between 5 and 10 days or >10 days Health promotion: Disease specific medication	Measles	Rash, high fever, cough, runny nose, red and watery eyes; serious post measles complications – diarrhea, pneumonia, croup	Person to person by airborne respiratory droplets	Dependent on baseline immunization coverage, especially in children under 15 years old Incubation period of 10–12 days	Watson et al. (2007) and Waring and Brown (2005)
	Neisseria meningitides – Meningitis	Sudden onset fever, rash, neck stiffness, altered consciousness, bulging fontanelle in under 1 year of age	Person to person airborne transmission via respiratory droplets	Responds quickly to antimicrobial prophylaxis Incubation period of 2–10 days	Watson et al. (2007) and Waring and Brown (2005)
	Streptococcus pneumoniae, Haemophilus influenza, or viral Acute respiratory infections (ARI) – Pneumonia	Cough, difficulty breathing, fast breathing, chest indrawing	Person to person by airborne respiratory droplets	Particularly affected children under 5 years old Risks include crowding, exposure to indoor cooking using open flame and poor nutrition Incubation period of 1–3 days	Watson et al. (2007) and Waring and Brown (2005)
Vectorborne diseases Onset: >10 days Health promotion: Vector control	*Plasmodium falciparum, P vivas* – Malaria	Fever, chills, sweats, heard and body aches, nausea and vomiting	Mosquito due to standing water after meteorological events creates breeding sites	Incubation period of 7–30 days	Watson et al. (2007) and Waring and Brown (2005)
Disease specific medication	Dengue	Sudden onset severe flu-like illness, high fever, severe headache, pain behind the eyes and rash	Mosquito due to rainfall and humidity creating breeding site	Risks include changes in human behaviour (i.e. sleeping outside). Incubation period of 4–7 days	Watson et al. (2007) and Waring and Brown (2005)
	Flavivirus – Japanese encephalitis	Quick onset, headache, high fever, neck stiffness, stupor, disorientation, tremors	Mosquito	Incubation period of 5–15 days	Waring and Brown (2005)
	Flavivirus – Yellow fever	Fever, backache, headache, nausea, vomiting, toxic phase-jaundice, abdominal pain, kidney failure	Mosquito	Incubation period of 3–6 days	

Wound related	*Clostridium tetani* – tetanus	Difficulty swallowing, lockjaw, muscle rigidity, spasms	Soil	Risks: Contamination of exposed wounds if vaccination is low	Watson et al. (2007)
Onset: 5–10 days					
Health promotion: Medication				Incubation period of 3–21 days	Waring and Brown (2005)
Other	Coccidioides immitis		Fungus found in soil in certain semi-arid areas of North and South America	Risk due to airborne dust after landslides following earthquakes	Watson et al. (2007)
	Mortality	Trauma		Health promotion includes safe body disposal	WHO (2005)
		Drowning			
	Morbidity	Injury		Onset in 1–3 days	WHO (2005)
		Near-drowning		Health promotion includes injury management and health needs assessment	
	Infections	Skin infections		Onset in 5–10 days	WHO (2005)
		Conjunctivitis			
		Ear infections			
		Dermatitis			

Compiled from scientific articles by Watson et al. (2007), Waring and Brown (2005) and WHO (2005)

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