Chapter 12

Disasters and Public Heath — An Updated Review of the Role of Infectious Disease in the Post-Disaster Environment

David M. Claborn and Christie Oestreich

Additional information is available at the end of the chapter

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1. Introduction

Both natural and man-made disasters affect the public health of impacted populations. This simple truth has been recognized for many years and several reviews and treatments of this topic have been written to provide perspective on how to prepare and respond to the impacts of disaster. One of the most complete of these treatments is the 1997 book edited by Erik Noji titled "The Public Health Consequences of Disasters." This comprehensive book compiled many of the lessons learned from disasters and conflicts that occurred in the latter part of the 20th century and then constructed some essential theory for public health workers who must contend with the post-disaster environment. Since the publication of that book, several noteworthy disasters have struck in various parts of the world: the Fukushima tsunami and subsequent nuclear power plant disaster, the Haiti earthquake of 2010, Hurricane Katrina, the Kashmir earthquake of 2005, Hurricane Sandy, the Indonesian tsunami, and many others. These and other disasters have added more insight into the field of public health as applied to preparedness for and response to disasters. More nuanced understanding has become available for how infectious diseases and mental health issues impact affected populations in the post-disaster environment. This chapter will attempt to update some of the information gained from these disasters.

2. Generalizations about Public Health and Disasters during the 20th Century

The rarity, unpredictability and suddenness of disaster occurrence historically led to a degree of neglect regarding the study of public health consequences of those disasters [1]. However,

the sheer magnitude of the number of people affected by disasters eventually demanded a systematic analysis of public health issues. The number of people killed, injured, or displaced by disasters was estimated to be 311 million in 1991, a tripling of the population since 1980. This increase was due to multiple factors including population growth, but was also due to denser urban populations, especially along coastal areas, and to a large migration of populations from rural areas to the urban setting. Further complicating issues was an increasing reliance on a sophisticated, but vulnerable, infrastructure to provide power, transportation, and daily essentials to the densely packed urban populations. All of these factors contributed to increases in the amount of damage caused by natural and man-made disasters. Concurrent with this reliance on an increasingly vulnerable infrastructure was an increase in the number of complex humanitarian emergencies, a special category of emergency defined as humanitarian crises in which there is a breakdown of authority as a result of internal or external conflict [2]. The complex humanitarian emergency by definition requires an international response that is beyond the capability of any ongoing country program. All, of these factors led to the realization that a systematic study of public health and disasters was warranted.

One consistent finding from these studies was that displaced populations were particularly vulnerable to disease and other impacts of disaster. Population movements after disasters may move people into regions where health services cannot provide adequate support, with the result being increased morbidity and mortality [1]. Increases in infectious disease have also been noted in these displaced populations, often due to increasingly unsanitary conditions and the lack of potable water. Epidemics of infectious disease after rapid onset disasters are considered uncommon, but this is not the case for complex humanitarian emergencies [3]. In Africa, there have been epidemics of shigellosis, hepatitis and meningitis directly associated with complex emergencies. Displaced populations have also experienced outbreaks of cholera, bacillary dysentery, measles, malaria, schistosomiasis, and leishmaniasis. For example, a significant epidemic of leishmaniasis in southern Sudan was associated with a population that was displaced by civil war [4].

The assumption that epidemics inevitably follow disasters has been described as one of several myths about disasters [1]. Other erroneous assumptions include perceptions that medical volunteers of all medical backgrounds are necessary, all types of international assistance are needed immediately, disasters elicit criminal human behavior, affected populations are too shocked to help themselves, moving affected persons into temporary settlements is desirable, food supplements are always required, and that clothing is always needed to support the affected population. These and other myths may misdirect efforts or lead to a large degree of inefficiency during relief operations. For instance, one of the most frequently donated items is used clothing, most of which is not needed. Unnecessary supplies clog up the logistics and supply system, preventing the rapid arrival of truly necessary supplies. Piles of extraneous clothing and other unnecessary supplies often have to be burned simply to obtain necessary warehouse space.

Myths aside, several consistent recommendations regarding the practice of public health after disasters have been described. Perhaps the most important of these is the requirement for potable water. A sufficient amount of water is the most important commodity for a recovering population. This was most graphically demonstrated when a cholera epidemic occurred

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amongst the Rwandan refugees inside Zaire in 1994. The estimated death toll was more than 50,000 people [1]. Second to the provision of adequate food and water is the need for shelter, especially for displaced populations. However, communal shelters can present special problems, especially with regard to infectious disease and at times, security. In communal shelters it is particularly important to institute surveillance for diarrheal illnesses, upper respiratory infections and vaccine-preventable diseases. In 1997, a group of non-governmental organizations and the Red Cross movement collaborated on a project to identify minimum standards for disaster assistance in the fields of water supply, sanitation, nutrition, shelter and health services. This process eventually led to the publication of the first Sphere handbook in 2000. This book, which has been used extensively to guide disaster relief and humanitarian assistance in many situations, is currently in the third edition and is free for download at sphereproject.org [5].

3. Disasters and public health in the early 21st century

As mentioned earlier, one of the basic understandings concerning public health in post-disaster environments is that rapid onset disasters rarely lead to epidemics of infectious disease, especially among the healthy. As with almost all assumptions involving biology, there are exceptions to this rule and some have occurred in the 21st century. Post-disaster communicable diseases have been categorized into four groups: (1) those due to contaminated water, (2) respiratory infections (3) vector-borne diseases and (4) infections due to wounds and injuries [6]. The top five causes of death due to infectious disease after disasters are diarrhea, acute respiratory infections, measles, severe malnutrition and, in regions where it occurs, malaria. Between 1999 and 2008, over 7,100 natural disasters occurred causing approximately 1,243,000 deaths. Most of these deaths, especially those linked to communicable disease, occurred in Asia. However, increases in infectious disease rates after disasters also occurred in developed countries. For instance, the rates of West Nile virus neuroinvasive disease, one form of which is a paralytic disease reminiscent of polio, increased more than two-fold after Hurricane Katrina in portions of Louisiana and Mississippi that were affected by that storm [7]. Researchers speculated that the increased number of cases was due to increased human exposure to vector mosquitoes caused by the necessity of living in damaged houses without proper windows or screens. There was also an increase in the mosquito population due to increases in larval habitat as a result of the storm. In that instance, there was a sharp decrease in cases of the disease soon after aerial application of insecticides, suggesting that such vector-borne diseases are subject to effective control.

Another example of a post-disaster outbreak is provided by a fatal fungal disease that appeared after the 2011 tornado in Joplin, Missouri. The storm itself directly caused approximately 160 deaths, but in the aftermath, an outbreak of necrotizing cutaneous mucormycosis occurred, with thirteen confirmed cases. Five of the cases were fatal. Each of the cases had suffered from significant deep-penetrating trauma during the tornado and thus were examples of "infections

following wounds and injuries." At least some of the victims were already in poor health prior to the storm; however, deaths were attributed to the infection.

Such fungal infections are not unique to the United States. Invasive fungal infections have been detected following eight different disasters including hurricanes, tsunami, an earthquake, a dust storm and a volcano. Other skin diseases are relatively common after disasters and have especially been associated with floods [9]. Prolonged immersion leads to keratinocyte damage and inflammation even without a typical immune cascade response [10]. This inflammation is often followed by a bacterial or fungal infections of the skin. Skin diseases as a result of flood exposure, can be categorized into four groups: inflammatory skin disease or irritant dermatitis, skin infections (usually bacterial or fungal), traumatic skin conditions, and miscellaneous. The latter includes insect bite reactions and psycho-emotion aggravation of existing primary skin diseases. The 2004 Indian Ocean tsunami led to many fungal skin infections, but also to several non-skin associated conditions. In one, an anesthetic was contaminated with a fungus, leading to infection of several delivering mothers receiving spinal anesthesia [9].

Although perhaps not as deadly as the example just mentioned and not caused by infectious disease, adverse birth outcomes have been repeatedly and consistently documented after disasters. Increases in rates of hypertension, anemia, pregnancy loss, birth defects, low birth weight, pre-term birth, intra-uterine growth restriction and decreases in head circumference have been attributed to trauma or exposures during or after disasters [11]. Also of importance to women's health, after Hurricane Katrina there was a documented increase in the rate of intimate partner abuse among displaced women, nearly three times that of pre-storm rates.

Due to the terrorist attacks of 2001 in the USA and subsequent attacks in Spain and London, public health agencies have had to assess what roles they must plan in preparing and responding to violent attacks on the civilian population, especially those associated with terrorism. Though this threat was not really new, the scope of the disasters mentioned above clearly required a public health response beyond that most agencies were capable of providing at the time. One significant challenge associated with terrorism is that terrorism's impacts go beyond the very obvious ones of illness and injury to cause significant increases in rates of anxiety and other psychological reactions. It is not surprising that the terrorists' actions cause such issues given that the goal is often to bring attention to the terrorists' causes through violence and terror. Such actions, by definition, are aimed at the mental well-being of populations. As professionals concerned with population health, the public health community often must become involved in disaster response following terrorist attacks and other violent events. Unfortunately, the success that developed countries have had in controlling disease may have led to a degree of complacency. In many ways, the public health infrastructure had somewhat deteriorated by the early years of the 21st century, leaving populations vulnerable to the repercussions of terrorism and other disasters. Laurie Garret discussed this issue at length in her book "Betrayal of Trust: The Collapse of Global Public Health" which was published just one year prior to the 2001 terrorist attacks. The threat of bioterrorism in particular suggested a need for improved epidemiology and disease surveillance, as well as more public health

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laboratories. Specific vaccines and anti-toxins were also needed, and several authors noted a need for improvements in mental health care capacity [18].

At the same time, the public health community expressed a concern that increased attention on responses to terrorism might take needed resources away from struggling but needed public health programs. The increasing likelihood that public health workers might have to work closely with law enforcement following bioterrorism events also raised fears that the public's trust in the public health community might be compromised. Nevertheless, the public health community demonstrated a needed capacity to respond to the needs of impacted populations after the attacks of September 11, 2001 [19]. Initial actions to assess health care availability and threats to those facilities were soon followed by environmental health sampling and public health education on re-entry and clean-up techniques for returning residents. Long-term efforts were initiated to establish surveillance programs on workers injuries and health. Also, environmental health actions after the building collapse were performed to ensure food and water quality, as well as adequate rodent and vector control.

Bioterrorism preparedness took on added importance after the anthrax attacks of 2001. There had been several hoaxes using powders to mimic an anthrax weapon previously, but the 2001 attacks were real and they utilized a weapons-grade formulation of the agent. The attacks led to 18 definite cases of anthrax disease, of which five were fatal. The attacks also contaminated portions of the mail delivery system, apparently causing infections in non-targeted persons far from the initial attacks. The anthrax attacks demonstrated the vulnerability of American society to bioterrorism and they stimulated much discussion about the need for a comprehensive bioterrorism plan. Discussions focused on the need for rapid detection and diagnosis, improved investigations and therapy, and effective communication. This latter was considered to be one of the larger extant problems due to unidentified lines of authority between the public health and law enforcement communities.

In the USA, the establishment of the Department of Homeland Security was a direct action to address many of the vulnerabilities to terrorism; however, officials noted that terrorism was still a rare event and that infrastructure built to address only the threat of terrorism would probably be unused for years at a time. The "all-hazards" concept of planning and response to disasters and threats to the homeland was developed to allow public health, public safety, law enforcement and other organizations with disaster response capabilities to be used on a variety of hazards whether related to terrorism or not. The concept stated that assets appropriate for a bioterrorist attack would also be appropriate for detecting and addressing other threats, such as natural outbreaks of a highly infectious disease (ex. avian influenza). In recent years, many investments in public health infrastructure have been related to the "all-hazards" approach that includes a homeland security focus.

4. The Haiti earthquake as an exception to many of the rules

Disaster events sometimes serve as turning points with regard to how organizations think about preparedness and response. For instance, the San Francisco earthquake of 1906 changed

the way public assets, especially the military, were used in disaster relief efforts [12]. Hurricane Katrina and the 9-11 attacks caused responders to focus on improved communication in post-disaster response [13]. The 2010 earthquake in Haiti may serve as another of those turning points, particularly with regard to the risk of infectious disease in the post-disaster environment. Public health authorities have maintained that outbreaks of infectious disease are rare after many disasters, including earthquakes. Experience with many previous such disasters supported this claim, but post-earthquake Haiti proved to be an exception---with caveats.

The 7.0-magnitude earthquake struck the island nation on January 12, 2010 just west of the capital city of Port-au-Prince. Government estimates placed the number of dead at 217,000, with many more injured or rendered homeless. The recovery process has been long and incomplete. Reports of some infectious diseases, like malaria, did go up in the native population, though the degree to which increased surveillance played a part in those increases is unclear.

Several countries provided substantial aid to the stricken population and many relief workers, including UN peacekeepers, arrived to provide a variety of essential services, from engineering to medicine. This was the population in which the rate of infectious disease was specifically noted. There were documented outbreaks of dengue and *Plasmodium falciparum* malaria amongst international travelers, as well as acute diarrhea and upper respiratory infections. The latter was specifically noted to occur at higher rates in post-earthquake travelers than in the population of pre-earthquake travelers [14]. In one group of American missionaries, 25% were infected with the dengue virus [15].

The above-mentioned diseases, however, had been endemic to Haiti for many years. After the earthquake, a new disease emerged, one that had not occurred on the island previously. That disease was cholera. The first cases of cholera in Haiti were detected in October 2010. Within two months, cases were occurring throughout much of the island. By mid-December, the daily death rate was estimated to be 100. By 2012, over half a million people had suspected infections and over 7,000 had died [16]. The earthquake-damaged infrastructures for providing water and other necessities exacerbated the disease situation, but a real mystery developed as to where the causative organism, *Vibrio cholarae*, had originated. Haiti had no real history of cholera outbreaks and had even avoided the 1991 pandemic [17]. Initial conjectures were that *V. cholerae* is a normal but dormant part of many coastal waters and that an event that causes significant disruption to the environment, such as an earthquake, can stimulate an outbreak of the disease [16]. Others thought that humans must have brought the agent from another endemic region and this appeared to be corroborated by sanitation issues occurring at a United Nation camp in which soldiers from endemic regions were encamped. Some even linked the initial outbreak to one event in which a septic tank was dumped directly into a tributary of the Artibonite River. Microbial studies provided strong evidence that the bacterium was a recent import from the region of Northern India or Nepal. The obvious conclusion was that the Nepalese UN peacekeepers were the source of the agent and the epidemic.

Through late 2012, 604,634 cases of cholera had been reported by the government, along with 329,697 hospitalizations and 7,436 deaths. Though still too high, the relatively low death rate

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reflects a remarkable success given that untreated cholera may result in nearly 50% death rates in affected populations. International workers were also infected and sickened.

Thus, the perception that infectious disease outbreaks are not common after earthquakes was not accurate for the Haitian situation. Of course, Haiti presents a variety of complicating factors that affected the post-earthquake disease risk. Haiti is a tropical island with the accompanying risk of tropical diseases; malaria and dengue, though not strictly tropical, are certainly more common in tropical regions. Also, Haiti is the poorest country in the Western Hemisphere. Many diseases, including cholera, have long been associated with poverty, so it is not that surprising that these diseases emerged in post-earthquake Haiti. Nevertheless, Haiti demonstrates that there are exceptions to most rules. It is still true that large outbreaks are rare after earthquakes and some other disasters, especially if those disasters occur in developed countries. That conclusion is not as easily accepted in developing countries, especially those in tropical regions.

5. Conclusion

The disasters mentioned here and others have added knowledge and insight to provide a better understanding of the preparation needed to prevent adverse outcomes in the post-disaster environment. With the increase in the number of people affected by disasters, whether being killed, injured, sickened or displaced, a need for a public health response was warranted in each instance.

There have been many myths and assumptions stating the needs of persons after disasters; these have often proved false and have actually caused confusion and great wastage. Numerous disasters have demonstrated that the main need after disasters is potable water, often followed by food and shelter. In addition, the most at-risk population for adverse health outcomes is that of persons who have been displaced in the post-disaster environment. The health outcomes of these disasters can include the rapid spread of infectious diseases. Although uncommon after disasters, they do occur on occasion. The highest risk of infectious diseases exists outside the developed world; however, recent events have shown several instances of infectious diseases after disasters in developed countries as well, including West Nile virus after Hurricane Katerina and a fungal infection that appeared after the Joplin Tornado. Other outcomes that have come to be of concern are adverse birth outcomes and mental health issues. In addition, with the recent surge in terrorist actions, public health has had to develop the ability to respond to these events as well.

Preparedness for disasters is essential for a fast and effective response, but an important question that plagues public health is to what degree funding is allocated for these programs. It is important to avoid reducing funding for already struggling but necessary programs. The challenge public health professionals must address is the need to find a balance between allocating the proper funds to ensure essential preparedness programs are prepared for future disasters while not hindering other critically important public health programs.

Author details

David M. Claborn and Christie Oestreich

*Address all correspondence to: davidclaborn@missouristate.edu

Master of Public Health Program, Missouri State University, USA

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