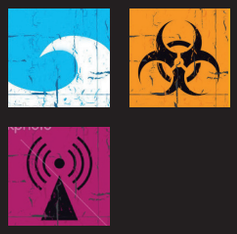

Chapter 11

Infectious Diseases Following Disasters

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Preface

Infectious diseases following natural disasters tend to emerge as a result of the prolonged secondary effects of the disaster, mostly when there is an interruption of public health measures resulting from destruction of the local infrastructure. This chapter will review infectious risks that occur as a result of natural disasters, reviewing the basic principles of post-disaster infectious diseases, diseases associated with specific types of disasters, and the public health interventions that should be considered.

Contents

Infectious Diseases Following Disasters

Infectious diseases following natural disasters emerge as a result of the prolonged secondary effects of the disaster, mostly when there is an interruption of public health measures resulting from destruction of the local infrastructure. Infectious disease outbreaks following disasters are rare if there is little or no displacement of the population. Outbreaks more commonly occur post disasters if there has been population displacement, particularly if the displacement is prolonged and associated with comorbidities such as malnutrition. It is crucial that post-disaster risk assessment take into account infectious issues for the potential risk and impact that they represent. As evidenced from prior disasters, the precise impact of infrastructure destruction is variable and contingent on the pre-disaster baseline, for example, if the preexisting level of sanitation is very poor, then a disaster may have little impact on baseline rates of infectious disease. The converse is also true, in that a highly developed infrastructure with a low baseline disease rate can offer a significant reserve capacity that can lessen the perceived impact of the disaster.[1] Thus, it is difficult to predict the risk of infectious disease outbreaks following a disaster simply based on the magnitude of the event itself.

There are 3 overlapping concerns that have synergistic effects and are helpful in predicting the risk of post-disaster infectious diseases:

1. new pathogens introduced into a community without preexisting immunity;
2. a change in the susceptibility of the population; and
3. an increase in the potential for transmission of local pathogens.

These will be discussed in turn, followed by examples of specific types of disasters and their associated infectious risks and the principles of risk assessment in response to a disaster.

Principles of Post- Disaster Infectious Diseases

New Pathogens

As many historical examples illustrate, the introduction of new pathogens into a population increases the risk of infectious outbreaks. Disasters commonly provide the means for the introduction of these new pathogens, thereby bringing low-incidence endemic diseases to the forefront. The postflood environment, for example, is a prime breeding ground for fungi and mold. Freshly flooded homes and buildings pose infectious risks.[2] The aeration and spread of soil and particulate matters have the potential to introduce new earth-borne organisms into the environment, specifically fungi such as histoplasmosis and coccidioides.[3] Collapsing wood and chaotic debris increases the risk of tetanus exposures. New mosquito habitats are created in the post-disaster flotsam, thereby increasing the risk of mosquito-borne illnesses such as malaria, West Nile virus (WNV), or dengue. Waterborne pathogens have been

documented to cause wound infection in the post-flood situation, notably during the post-Katrina response.[4]

The infectious risks posed by dead bodies have been greatly examined, and there are no data to suggest that the body of a person killed in a disaster who is free of infection at the time of death will pose any risk of infection to others, despite common misconceptions.[5,6] Appropriate public education is vital to disseminate knowledge of World Health Organization (WHO) guidelines stating that every effort should be made to identify and bury or cremate the corpse, all the while respecting appropriate customs and laws.[7] Typical universal precautions for body fluids should be observed. Concern about dead bodies will persist among workers and evacuees,[8,9] and reassurance should be given by the disaster services provider.

Altered Susceptibilities

Populations in movement or stress are more susceptible than normal to infectious diseases. This vulnerability comes from mechanical factors such as the compromise of personal hygiene and the presence of disaster-related wounds,[10] and biological factors such as a potentially compromised immune response due to the stress, hypothermia, or malnutrition associated with the post-disaster environment. Interruption of vaccination and other public health programs (e.g., tuberculosis [TB] treatment, HIV therapy) may lead to populations with susceptibility to vaccine-preventable and other infectious diseases.

Increased Potential for Transmission

Although not specific to any one type of disaster, populations displaced from their homes, clustered in close proximity and spending time in closed spaces are at an increased risk for infections, especially respiratory and gastrointestinal illnesses. The enteric viruses, such as norovirus or rotavirus, have been implicated in outbreaks of gastroenteritis in the post-disaster setting.[11–14] The risk of TB transmission is increased with close contact living and should be anticipated particularly in areas with high endemic rates of TB whether or not access to medications is interrupted. Transmission of acute respiratory viruses has been well documented in the close conditions of the post-disaster setting.[15] Airborne outbreaks of pathogens, especially measles, are also significant risks that need to be considered and have been associated with higher rates of pneumonia and death in displaced populations.

In all of these situations, an increase in the basic reproductive number (R_0) of previously low-incident diseases is primarily attributed to an increased population density and closed conditions in the post-disaster setting. Therefore, the threshold vaccination rate required to achieve herd immunity is increased, so that if previously it stood at 85%, it may rise to 95% in the post-disaster setting[16] (see Figure 11-1). This increased potential for disease transmission must be taken into account when discussing any program implementation, including shelter, sanitation, food distribution, and health care.

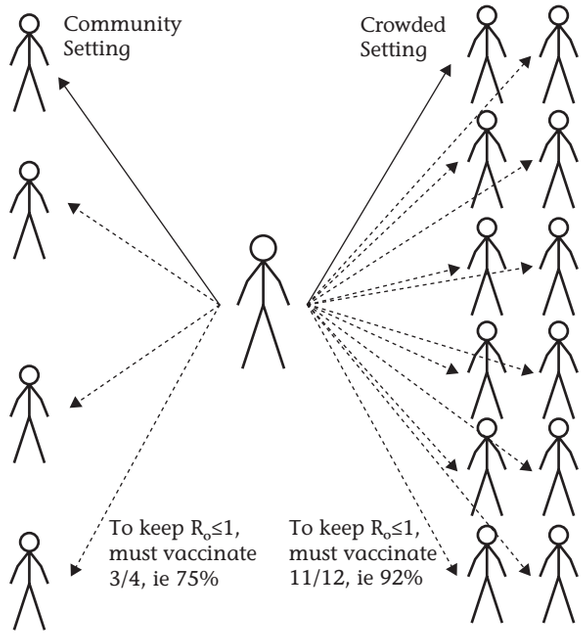

Figure 11-1: Increased potential for transmission in the post-disaster setting causing an increased threshold of herd immunity required to stem outbreaks of infectious diseases.

Specific Types of Disasters

Floods and Tsunamis

Floods are one of the most frequent of all natural disasters. Drinking water contamination is the most frequent concern from an infectious diseases perspective, with numerous historical epidemics of post-flooding gastrointestinal illness.[17–20] There are also examples, however, where significant flooding and subsequent water system damage occurred without any documented outbreaks.[21–23] When outbreaks have occurred, they have typically been associated with previously endemic organisms, such as Shigella[19] and Giardia,[17] although most cases have no etiologic agent identified.

A study of water quality that was ongoing when a major flood of the Mississippi River occurred provides an interesting insight into this situation.[20] Source drinking water concentrations of both *Giardia* and coliform species significantly increased (330% and 270%, respectively) postflood. The two major factors that increased an individual's risk of diarrhea were whether the individual's house or yard was flooded and whether they assisted with clean-up efforts. The availability of safe potable water from active water purifying devices had no discernible effect. This suggests that infection actually occurred through a route other than the consumption of contaminated drinking water in this case, and that source water purification may not play a significant role in attenuating outbreaks. Similarly, following the 1998 Bangladesh floods factors such as crowding, lack of latrine use, lidless water storage containers, and the use of small storage containers for water were all associated with increased rates of diarrheal illness.[1,18] This again illustrates that factors beyond simply a supply of clean source water are important to prevent disease, and that educational

interventions regarding appropriate hygiene and infection prevention are crucial. Common causes of diarrheal and other infectious illnesses post-disaster are listed in Appendix C.

In addition to contaminated drinking water, flooding also raises the theoretical specter of increased vector-borne illnesses due to increased mosquito populations.[1,22] Following the 1993 Iowa floods, a significant increase in the number of mosquitoes was documented, although without an accompanying increase in the endemic, but sufficiently rare, Western Equine Encephalitis (WEE).[21] Fifty-five human cases of WEE and 12 cases of St Louis encephalitis (SLE) were reported after flooding in North Dakota and Minnesota in 1975. After Hurricane Katrina, statewide surveillance in Louisiana and Mississippi did not show an increase in either WNV or SLE; however, local surveillance revealed a dramatic increase in WNV neuroinvasive disease in hurricane-affected areas when compared with areas in the states that were not affected by the hurricane.[63,64] Relief workers aiding the recovery efforts following Hurricane Georges in Puerto Rico did not contract the mosquito-borne dengue fever, despite being in the midst of an epidemic of dengue fever.[23] Although vector-borne disease outbreaks are rare in North America and other areas where adequate mosquito abatement programs exist, there have been large outbreaks of malaria recorded after flooding in other countries including Mozambique in 2000, Sudan in 1985, and Bangladesh in 1989–1991.[65] The increased morbidity and mortality in these disasters are likely from combinations of an increase in vectors, poor environmental conditions, interruption of mosquito control programs, increased populations exposed to the vectors while living outside, lack of access to health care, and increased vulnerability due to malnutrition. Arthropod-borne infections pose a risk after flooding and other water-related events that is dependent on the endemic risk in the affected area. Therefore, education and preventive measures against such infections should be part of a disaster response plan.

Another specific risk posed by floods is mold growth due to water damage. After Katrina and Rita in New Orleans, household levels of fungal by-products were significantly higher in severely flooded homes, specifically the fungi *Aspergillus Niger*, *Penicillium* spp, *Trichoderma*, and *Paecilomyces*, all of which cause human disease. There was no significant human outbreak of these illnesses post-Katrina, although a theoretical risk exists in future disasters.[2,24]

Wound infections, dermatitis, conjunctivitis, and ear and throat infections have all been recorded after flooding and, in particular, in the aftermath of the 2004 tsunami in Southeast Asia. Most infections are the result of direct skin or mucous membrane contact with contaminated fresh or salt water. The most commonly isolated microorganisms are *Staphylococcus* and *Streptococcus*; however, outbreaks of leptospirosis have been reported after flooding in Hawaii, Nicaragua, Puerto Rico, India, and Bangladesh. Skin infections with waterborne organisms like *Aeromonas* spp, *Vibrio* spp, and other gram-negative rods have been recorded. In particular, 18 cases of *Vibrio* wound infections were reported after flooding following hurricane Katrina. Of the identified species, 14 were caused by *Vibrio vulnificus* (with 5 deaths) and 3 were caused by *Vibrio parahaemolyticus* (with 2 deaths).[27] After the tsunami, a report on skin and soft tissue infections from Thailand found over 70% were polymicrobial with 2 organisms recovered from 41% of specimens and 3 different organisms isolated from 24%. *Burkholderia pseudomallei* caused infections ranging from skin and soft tissue infections to sepsis, pneumonia, and secondary abscesses was reported following the tsunami in both locals and in returning travelers to several countries where *B. pseudomallei* is not endemic.[66,67] Other travelers who

survived the tsunami reported unusual skin and wound infections from a variety of bacteria and fungi including *Aeromonas hydrophila*, *Apophysomyces elegans*, *Pseudomonas aeruginosa*, and *Mycobacterium abscessus* and *M. chelonae* most not normally endemic in their home countries. Rapid response to these infections and active surveillance to determine common causes are essential parts to these kinds of disaster response and recovery efforts.

Hurricanes, Cyclones, Tornadoes, and Typhoons

Hurricanes, cyclones, and typhoons share a great deal in common with floods in terms of their post-disaster impact. The storm surge itself is responsible for most of the death and injury, and the post-disaster issues are similar to flooding.[25] In one example, a very large outbreak of diarrhea occurred with 97,934 cases following a cyclone in India.[8] Molecular analysis confirmed that this outbreak was due to endemic strains of *Vibrio cholera*, *Escherichia coli*, and *Shigella*, although with a much lower case fatality rate compared with pre-disaster baseline.

Tornadoes share the ferocious powers of the wind with hurricanes, but they lack the storm surge and flooding that accompany hurricanes. They occur with greater frequency and tend to affect inland areas more than hurricanes, at times spawning from remnants of hurricanes. Although tornadoes themselves have not been reported to directly result in infectious disease outbreaks, wound infections due to traumatic injuries contaminated with soil or water incurred during a tornado have been reported and risk of tetanus exists in people who have not had a primary series or recent tetanus booster.[26]

Earthquakes

Earthquakes are one of the most dramatic, rapid, and destructive natural disasters that occur. The loss of life and injuries can be numerous following an earthquake, although the risks of infectious outbreaks are relatively low.[9,27,28] In fact, nearly 95% of injuries and deaths due to earthquakes occur within minutes of the quake.[27,28] Even in a situation where significant damage has been sustained to public infrastructure and thousands of people are homeless, outbreaks have rarely occurred immediately following earthquakes.[9,29]

When outbreaks of illness do occur following an earthquake, they are typically the result of an increased incidence of endemic pathogens. Following the Northridge earthquake in California in 1994, Ventura County experienced an outbreak of 203 cases of Coccidioidomycosis, including 72 deaths, as a result of dust clouds created during landslides.[3,27] Following an earthquake in Turkey, a large but brief outbreak of diarrhea was noted,[30] although with no significant change in the baseline rates of isolation of endemic pathogens, prompting the authors to speculate that either emotional stress and/or a sudden change in the diet of displaced persons was to account for the illnesses documented.

A unique property of earthquakes is their ability to cause tsunamis. Tsunamis combine both powerful destructive forces along with flooding, resulting in a very unique disaster. Aside from drowning, the most common serious injuries reported following the Southeast Asian tsunami in 2004 were large flap lacerations.[31,32] As described earlier, there were several reports that wounds were grossly contaminated with seawater, coral, or soil, causing infections by often drug-resistant organisms such as *Acinetobacter*, *Pseudomonas*, *Stenotrophomonas*, *E. coli*, *Aeromonas*, and *Mucor*. Transmission of infectious disease can occur only

if the organism is endemic in the area where the disaster occurs and this is reflected in many unusual infections seen after the tsunami in Southeast Asia. These infections can show up, however, in other countries as also seen after the tsunami when many victims and relief workers returned to their home countries with infections acquired in the tsunami zone.

Displaced Populations

A unifying feature of the post-disaster environment is the presence of displaced population. As was widely publicized during hurricane Katrina, those evacuated to emergency shelters often faced crowded living conditions creating situations vulnerable to communicable disease outbreaks. Outbreaks of Methicillin Resistant *Staphylococcus aureus* (MRSA) skin infections and gastrointestinal illnesses were common in post-Katrina evacuation centers.[4] People sheltered in buildings with one large room, such as churches or community centers, were at significantly higher risk of contracting an influenza-like illness than those in shelters with several smaller rooms, such as schools.[15] Following two hurricanes striking the Dominican Republic in 1979, community outbreaks of hepatitis, gastroenteritis, and measles occurred,[33] and disease rates significantly peaking from already elevated baseline rates *5 months after* the hurricanes.

When populations become displaced for long period of time, natural disasters can spawn complex emergencies that can prompt outbreaks of diseases such as malaria, meningitis, pneumonia, TB, and HIV.[34–39] Post-disaster crowding itself is a complex enterprise with all 3 of the above concerns including new pathogens, altered susceptibilities, and increased potential for transmission of infections synergistically resulting in a significantly increased risk of a diverse spectrum of infectious diseases.

Public Health Interventions to Prevent and Control Infectious Disease

Prevention and control of infectious diseases is a key public health intervention post-disasters, regardless of type. The initial risk assessment for infectious disease after a disaster should include assessment of the endemic and epidemic diseases that are present both in the affected area and the area to which people may have been displaced, the living conditions in the disaster area and areas for displaced people, the availability of safe water and adequate sanitation facilities, the underlying nutritional status and immunization rates of the population affected, and the availability and access to healthcare services for management of cases of infectious illness. The main functions that need to be put in place rapidly are assessment, establishing of water, sanitation, and other environmental systems that prevent disease, surveillance to detect infections early, protocols for rapid outbreak response and implementation of control measures, and individual case management of specific infectious diseases to prevent spread.

Immediate Infectious Disease Risks

The immediate issues that may need to be addressed following a disaster include management of wounds, injuries, and burns that could lead to tetanus, wound infections, and gangrene. This will usually involve the establishment of acute

health assessment and care centers where both infectious and noninfectious health care is provided. One key measure in response to population with low immunization rates and high numbers of traumatic wounds is the provision of tetanus immunization to individuals at risk.

Water, Sanitation, Hygiene-Related, and Food-Borne Disease

Contamination of water by damaged sewage systems and disruption of usual drinking water sources may lead to use of unsafe drinking water. Infectious concerns include common enteric organisms such as *E. coli*, *Salmonella*, and *Shigella*, as well as Hepatitis A and potentially E. Depending on the prevalence in some countries, *Salmonella typhi* (typhoid fever) and cholera may be important concerns as well. Finally, contact with urine from infected rodents can lead to outbreaks of leptospirosis. Ensuring the provision of safe drinking water may be the most important preventive measure in decreasing the risk of waterborne disease outbreaks and a safe water source for hygiene will prevent skin and wound infections. Establishment of latrines and designated defecation areas is another key measure to prevent the transmission of infection.

Infectious Diseases Associated with Displaced Persons

Addressing of diseases associated with crowding or which have increased morbidity and mortality in settings where there are large numbers of displaced persons is another key public health measure that will mitigate the risk of infectious disease outbreaks. Determination of the baseline immunization rates in the population (both those left in the community and people displaced by the disaster) is a key factor in the potential for outbreaks of measles, diphtheria, pertussis, and meningitis. Measles and meningitis, in particular, can have very high mortality in displaced persons (10%–30%) particularly in a setting of underlying malnutrition, diarrhea, or acute respiratory infections.

Surveillance should be established for rapid detection of these outbreak prone conditions and processes established for rapid delivery of vaccination should disease be detected. Acute respiratory infections are also a concern in displaced population and surveillance to monitor for and use of standard treatment protocols should be rapidly established.[70] Gastrointestinal illness caused by viruses such as norovirus can cause significant morbidity in displaced population and again systems should be established to detect illness rapidly so that control measures can be implemented immediately. TB may be a concern if there is a high prevalence in the community. People may not have access to their anti-TB drugs after a disaster and crowded conditions may lead to enhanced transmission. Poor nutrition over prolonged periods may trigger reactivation of latent TB and surveillance for new cough and fever should be established. The same concerns of access to antiretroviral medications may also be an issue for people with HIV and should be considered in a response to a disaster.

Vector-Borne Disease and Zoonoses

Dengue, malaria, yellow fever, and WNV have all been associated with outbreaks following disasters; routine response planning needs to include measures to reduce mosquito breeding sites and protocols for vector control and yellow fever immunization in specific countries.

Rabies can be a concern in some countries with high endemic rates in dogs that may be foraging and displaced as well during the disaster. In some areas, leptospirosis can also be a concern and measure should be implemented to prevent contact with urine of infected animals.

Vaccine-Preventable Disease and Routine Immunizations

Many vaccine-preventable diseases have an increased outbreak potential in displaced populations particularly when underlying immunization coverage rates are low and crowding is common. Particular concerns in post-disaster settings are measles, polio, diphtheria, and pertussis. Consideration should be given to proactive immunization with measles/rubella (either as MR or MMR) for all persons aged 6 months to 35 years who are displaced and living in crowded conditions; vaccine should be offered as soon as they enter a camp regardless of immune status (from previous immunization or history of measles). Surveillance programs should be established to monitor for meningococcal meningitis, yellow fever, and hepatitis A and plans put in place to initiate vaccination as an outbreak control measure should illness be detected. In general, population immunization with tetanus toxoid is not recommended but tetanus vaccination should be a routine part of wound management.

When the situation stabilizes, routine immunization programs should be set up as soon as possible. The routine vaccinations provided by the national immunization program should be made available to all infants, pregnant women, and others as part of provision of basic emergency healthcare services following a disaster. As a minimum, the immunizations given as part of the WHO expanded program on immunization (EPI) should be included. These include tetanus, diphtheria, polio, measles, and TB and in some countries, hepatitis B. Although immunization programs are well established in most EPI countries, the disaster may lead to disruption of public health programs leaving large number of people, especially children susceptible to vaccine-preventable diseases.

Emergency responders and relief workers should ensure that their immunizations are up-to-date before deployment. As a minimum, this should include protection for hepatitis B, diphtheria, pertussis, tetanus, polio, measles, mumps, and rubella and in addition, depending on the situation and the country involved, immunization for typhoid, rabies, Hepatitis A, yellow fever, and meningitis may be recommended.

Other Public Health Considerations

Individuals handling human remains may have a small risk through contact with blood, secretions and feces of hepatitis B and diarrheal illness, and a theoretical risk of hepatitis C or HIV. Anybody handling human remains should be instructed

on the basic hygiene measures to protect themselves; this includes wearing gloves and boots, washing hands with soap and water or alcohol-based hand rubs before eating and after their shift is over, avoiding touching their mouth, eyes, or face with their hands, and washing all equipment, clothes, and vehicles used for transporting of bodies.

Malnutrition can be a serious underlying issue in displaced populations and may lead to an increased vulnerability to infections particularly acute respiratory infections and diarrheal illness. HIV prevention, treatment, and care may be an important component of a disaster response and sexually transmitted infections may be an important cause of morbidity in displaced persons camps. This has been an issue in some displaced persons camps particularly if stays in the camps are prolonged. Issues of food security, domestic violence, lack of clean needles, blood supply disruption, and lack of availability of condoms may lead to increases of sexually transmitted infections and HIV. Infestations such as scabies and lice may also become a concern in crowded conditions with poor access to water and other hygiene measures.

Rapid Needs Assessment and Surveillance for Infectious Disease Outbreaks

Rapid needs assessment can be accomplished using standard simple tools such as questionnaires[68] that can be administered to a random cluster sample in a displaced person camp or in the community. This methodology has been used post-disaster to assess needs in several situations[68,69] including post hurricanes in the United States and after the devastating earthquake in Pakistan in 2006. These assessments can not only be used initially to determine the health response needs but can also be used as a surveillance tool for understanding baseline rates of illness and immunization.

Early establishment of surveillance systems to detect outbreaks and monitor for epidemic prone illnesses is key to a rapid and lifesaving response. Priority conditions to put under surveillance include the following:

- Acute watery diarrhea
- Acute bloody diarrhea
- Measles
- Acute respiratory infection
- Dengue
- Malaria
- Jaundice syndromes (Hepatitis A, E, and B)
- Meningitis
- Tetanus
- Unexplained fevers
- Unusual or unexpected public health events (e.g., clusters of illness, unexplained disease)

In particular, alert systems should be established for bloody diarrhea, measles, and dengue hemorrhagic fever; and standard treatment protocols should be

established for these epidemic prone diseases as well as cholera, dysentery, shigellosis, typhoid, hepatitis, malaria, influenza, STIs, and any other endemic infectious disease of concern.

A detailed outbreak response plan should be developed early to allow timely action to be taken to control outbreaks. This response plan should build on existing structures as much as possible and should identify key laboratory support.

Interventions

Many of the interventions should be centered on anticipatory prevention, given the risks of a significant infectious outbreak. Vital to these interventions is surveillance, both immediately post-disaster and in the subsequent weeks as the disaster response continues. The ability to detect greater-than-baseline incidences of diarrhea, respiratory illness, or fevers with rash is the cornerstone of any outbreak response.

Implementing appropriate universal- and transmission-based precautions at all times is vital for health worker safety and outbreak control. The availability of hand-washing stations, ensuring frequent and thorough hand cleansing, is the most cost-effective intervention to stem disease spread. Maintaining a focus on hygiene through ensuring clean food preparation and eating areas, appropriately placed lavatories, and containment of soiled areas is vital to prevent an infectious outbreak.[14,40] Post-disaster sheltering in many small rooms is preferable to few, large roomed housing, if feasible.

The typical historical response to a natural disaster has been to conduct mass vaccination or chemoprophylaxis campaigns.[1,9,41] Unfortunately, these campaigns are poorly organized and characterized by the administration of incomplete batteries of vaccine and inadequate record keeping. Each situation is unique, requiring providers to weigh the merits of vaccinating post-disaster evacuees who should be examined on a case-by-case basis.[42] In regions such as parts of Canada[43] or the UK[44] with rates of measles immunization of <90%, there may be a need to introduce measles mass-vaccination campaigns to achieve the new, higher threshold of herd immunity in the post-disaster crowding. Similarly, in developing world settings, the lower baseline vaccination rate, coupled with increases in R_0, makes preventive measles vaccination a priority in all children up to 14 years.[45,46]

The Centers for Disease Control (CDC) in the United States have routinely updated guidelines regarding immunizations in the post-disaster setting, encouraging updating tetanus, meningococcal, and pneumococcal series for those not up-to-date.[47] Varicella, influenza, and MMR vaccines should be considered in individuals living in crowded group settings, with targeted vaccinations for other at-risk population used to control outbreaks. Crucial to all of the above vaccination recommendations is adequate documentation of any intervention.[47]

The chemoprophylaxis and vaccination needs of responders to a disaster, ideally organized well before departure, should include provisions for HIV post-exposure prophylaxis following percutaneous exposures. Post-exposure chemoprophylaxis for documented cases of meningitis or rabies should be performed on an as-necessary basis. In addition, many patients will likely have chronic infectious issues, namely HIV, where access to medications will be a likely

concern.[48] It was estimated that up to 40% of people affected by Katrina lived with a chronic illness,[49] thereby making chronic disease exacerbations a concern.

Having a health center where there is limited exposure to other community members and easy access to medical personnel is a crucial component of infection control and triage for people with a suspected or documented infection.[50] Anticipatory preparation of these health and evacuation centers for the expected outbreaks, especially of diarrheal illness, should be performed. The creation of appropriate diagnostic centers with rudimentary laboratory facilities is a reasonable step for prolonged post-disaster conditions.[51,52]

The distribution of antimicrobials should be on a patient-by-patient basis by appropriately trained professionals. Appendix D lists the antibiotic-related contents of the most recent WHO emergency kit, which can be used as a guide in deciding on appropriate medications for the setting. Appendix E lists some considerations to take into account for those who wish to alter the antibiotic formulary for a specific setting. Once again, due to rapidly changing epidemiology, drug formulary selection should be performed on a situational basis, using the criteria listed below, with the emergency kit simply used as a backbone. Regional resistance rates to antibiotic (and antiparasitic, i.e., malaria) agents, if known, can be taken into consideration by relief agencies deploying healthcare resources to disasters.

Conclusions

Disasters, whether natural or manmade, have the potential to lead to outbreaks of infectious diseases. Despite common perceptions, outbreaks following a disaster are infrequent. Outbreaks are caused by endemic organisms when they do occur. The peer-reviewed literature discussing post-disaster infectious disease is limited. The main tools in prevention and treatment remain as follows:

1. infection control,
2. surveillance,
3. epidemiologic analysis, and
4. laboratory diagnostics.

By considering the type of disaster, endemic organisms, public health infrastructure, and baseline population characteristics, one should be able to predict with reasonable certainty what infectious agents may pose a threat following a disaster, therefore initiating a tailored response. Finally, there is a critical need to begin to include research into the disaster responses so that future responses can be evidence based thereby allowing resources to be directed appropriately.[25]

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Appendix A – Health Sector Priorities

Provision of sufficient and safe water
Access to surgical, medical, and emergency care, particularly for trauma, obstetric cases, wounds, and burns
Priority immunizations, including mass vaccination campaign for measles/rubella, and tetanus immunization as part of wound care
Communicable disease surveillance and response, including preparedness for epidemic-prone diseases
Support for appropriate infant and young child feeding and malnutrition management
Continuity of care for chronic diseases (e.g., HIV, TB, hypertension, etc.)
Public health communication
Non-health sector priorities impacting health
Shelter and site planning

Appendix B – Sequence of Public Health Interventions

Rapid Assessment	Identify the infectious disease threats and define the health status of the population.
Prevention	Prevent communicable disease by fostering a healthy physical environment and good general living conditions.
Surveillance	Set up an early warning mechanism to ensure the early reporting of cases of specific infectious diseases, to monitor disease trends.
Outbreak Control	Ensure rapid response by confirmation, investigation, and implementation of control measures.
Disease Management	Diagnose and treat individual cases of infectious disease promptly with trained staff using effective treatment and standard protocols at all health facilities.

Adapted from WHO.[47]

Appendix C – Selected Pathogens Implicated in Post-Disaster Infectious Diseases

Transmission	Disease/Agent	Clinical Features	Incubation Period	Diagnosis	Treatment	Prevention/ Control
Fecal/Oral	*Cholera Vibrio cholerae*	Profuse watery diarrhea, vomiting	2 h to 5 d	Microscopic observation of organism in stool	Intensive rehydration therapy; antimicrobials based on sensitivity testing	Hand washing, proper handling of water/food, and sewage disposal
	Bacillary dysentery *Shigella* spp	Malaise, fever, vomiting, blood and mucous in stool	12–96 h	Isolation of organism from stool	Nalidixic acid, ampicillin; hospitalization of seriously ill or malnourished; rehydration	Hand washing, proper handling of water/food and sewage disposal
	Viral Hepatitis Hepatitis A, E virus	Jaundice, abdominal pain, nausea, diarrhea, fever, fatigue, and loss of appetite	15–50 d	Serologic assay detecting anti-HAV/HEV antibodies	Supportive care	Hand washing, proper handling of water/food, and sewage disposal; Hepatitis A vaccine

(continued)

Transmission	Disease/Agent	Clinical Features	Incubation Period	Diagnosis	Treatment	Prevention/ Control
	Typhoid fever *Salmonella typhi*	Sustained fever, headache, constipation	3–14 d	Culture from blood, bone marrow, bowel fluids; rapid antibody tests	Ampicillin, trimethoprim-sulfamethoxazole, ciprofloxacin	Hand washing, proper handling of water/food, and sewage disposal; vaccination in some settings
	Viral Gastroenteritis Many, including rotavirus and norovirus	Diarrhea	3–7 d	Clinical, isolation of virus in stool	Supportive, hydration	Hand-washing, hygiene; environmental cleaning
Air-Borne	Measles Measles virus	Fever, conjunctivitis, cough, diffuse rash	10–14 d	Clinical, serology	Supportive	Vaccination, hygiene
	Respiratory viruses	Cold-type symptoms	3–7 d	Clinical	Supportive	Hygiene, hand-washing
	Meningitis *Neisseria Meningitis*	Fever, headache, stiff neck	2–10 d	Isolation of organism in CSF	Antibiotics	Post-exposure antibiotic prophylaxis, vaccination
Vector-Borne	Malaria *Plasmodium* spp	Fever	Varies by species, 9–40 d	Visualization of organism in blood, rapid test	Anti-malarial, depending on species	Mosquito control,
	Dengue fever	Fever, headaches, muscle pain	3–14 d	Clinical, serology	Supportive	Mosquito control

Appendix D – Infectious Disease-Related Contents of WHO Emergency Kit

Basic Kit	Benzyl benzoate, lotion 25% Chlorhexidine (5%) Chloroquine, tab 150 mg Gentian violet, powder Mebendazole, tab 100 mg Oral rehydration salts Sulfamethoxazole + trimethoprim, tab 400 mg + 80 mg Tetracycline eye ointment 1%
Supplemental Kit[a]	Amoxicillin, tab 250 mg Ampicillin, inj 500 mg/vial Benzathine benzylpenicillin, inj 2.4 million IU/vial Benzylpenicillin, inj 5 million IU /vial Chloramphenicol, caps 250 mg Chloramphenicol, inj 1 g/vial Doxycycline, tab 100 mg Metronidazole, tab 250 mg Nystatin, non-coated tab 100 000 IU/tab Nystatin vaginal tab 100,000 IU/tab Procaine benzylpenicillin, inj 3–4 million IU/vial Quinine, inj 300 mg/ml 2 ml/ampoule Quinine, sulfate, tab 300 mg tab Sulfadoxine + pyrimethamine, tab 500 mg + 25 mg

(continued)

The Kit Does Not Contain	Vaccines Drugs for tuberculosis Drugs for leprosy Drugs for specific resistant malaria strains Drugs for sexually transmitted infections

[a]Includes all contents of basic kit as well.

Appendix E – Considerations When Selecting Antimicrobials for Disaster Relief

The endemic organisms in the disaster area
Resistance patterns of these organisms
Ease of administration in the field (oral preferred over intramuscular preferred over intravenous)
Storage requirements (avoid drugs that require refrigeration or are damaged by freezing)
Expiration dates for drugs should not be less than 4 yr
Vaccines and Chemoprophlyactic agents
Constantly recall that providers are potential patients