DRAFT

Human Health Impacts of Hazards in Coastal Communities

by

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ABSTRACT

Natural disaster events can present unique impacts on human health in coastal communities, where residents may be directly susceptible to the physical and mechanical forces of hydro meteorological and geological phenomena such as high wind, heavy rain, flooding from unusually increased water levels due to tidal activity, and seismic activity from faults located in or near coastal areas. This paper reviews direct and indirect impacts of disaster events on the health status of residents of coastal communities in terms of impact deaths and injuries, deaths and injuries in cleanup and reconstruction, illnesses associated with debris and pollution, and chronic health effects and birth defects. Suggestions for directing continuing investigations are made so that mitigative strategies can be formulated to prevent or reduce morbidity and mortality in future disaster events.

KEYWORDS: health effects; coastal hazards; natural disasters; epidemiology; floods; hurricanes; earthquakes; prevention effectiveness.

1. INTRODUCTION

Natural disaster events -- such as flooding, hurricanes, and earthquakes -- of significant magnitude and severity can result in short- and long-term effects on human health and safety. In particular, these events present unique impacts on health in coastal communities, where residents may be directly susceptible to the physical and mechanical forces of hydro meteorological and geological phenomena such as high wind, heavy rain, flooding from unusually increased water levels due to tidal activity, and seismic activity from faults located in or near coastal areas. Disaster events and their impacts on human health further can be exacerbated indirectly by demographic and land use patterns that could potentiate risks to health and safety for human populations resulting from increasing settlement and population density along coastlines and expanding industrialization along coastal zones (1).

Disaster events - including hurricanes, nor'easters, winter storms, and El Niño-related storms, floods, and drought - are known to occur along the nearly 88,000 miles of U.S. ocean, estuarine, and Great Lakes shorelines (2). From 125 presidentially declared disaster events with 860 fatalities in the United States from 1994 to 1998, 791 deaths (92%) were climatic and 69 non-climatic, i.e., geological. Of the climatic-related deaths, 490 (62%) occurred in wind-related storms, 286 (36 %) in flood-related storms, and 15 (2%) in severe winter storms (3). Altogether, an annual average of 210,705 people were at risk for death, injury, or illness from these events from 1988 to 1997 (4). For hurricanes alone, in the United States, an annual average of 2 hurricanes develops sufficiently to make landfall along the Atlantic coast or the Gulf of Mexico, although many more develop in the course of a year. The National Weather Service estimates that of approximately 70 million people at risk from hurricanes, 50 to 100

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people are killed on average (5).

The public health consequences of natural hazards in coastal and inland areas - hurricanes, floods, and earthquakes, among others -- have been documented at length for numerous major disaster events occurring in the United States and throughout the world (6). At the individual level, these consequences have focused largely on "disaster-caused" or direct impacts, primarily fatalities, injuries, illnesses or other adverse health conditions resulting from the direct force of a hazard or from disaster-related activities, or other events that would not have occurred in the absence of the disaster event (7). Other consequences have addressed "disaster-related" or indirect impacts, such as those resulting from a preexisting condition exacerbated by deteriorating, interrupted public health and medical services or disruption of normal public health or medical programs in the pre, during, or post disaster phases. Finally, others have included possible impacts, such as those occurring during a disaster or during pre or post disaster activities although insufficient information precludes a clear determination of whether the impact was related, either directly or indirectly, to the disaster event.

Along coastal zones, however, the susceptibility of inhabitants in natural hazard settings is associated with unique geologic patterns and weather events that operate on varying spatial and temporal scales (2). As such, the health consequences of hazards occurring in coastal communities may arise primarily from changes -- either natural or human made --to water quality, the land-water interface, the built environment in coastal areas, and the interface between strong winds and the built environment. This paper examines the direct and indirect impacts, as determined in the literature to date, and raises potential effects of hazards on physical health in coastal communities.

2. MORTALITY AND MORBIDITY

2.1 Deaths and injuries from impact

Mortality and morbidity related to the impact of coastal disaster events have been examined in the context of forecasting and warning systems. With timely and accurate forecasting and warning, deaths and injuries are prevented or reduced by eliciting appropriate behavioral changes in individuals at risk, such as evacuation and safe sheltering.

Prior to modern developments in forecasting and warning technologies, drowning accounted for over 90 percent of deaths in cyclone-related events (8, 9). Despite advancements in technology, however, mortality and morbidity continue to recur during the pre impact, impact and post impact phases in recent disaster events. After Hurricane Hugo struck South Carolina and Puerto Rico in 1989, drowning accounted for 8 of 15 deaths during the impact phase (10). In the aftermath of Hurricane Floyd, which severely affected the North Carolina coast in 1999, drowning was the cause of 36 of 52 fatalities, 24 of which took place in motor vehicles (11).

Deaths due to blunt trauma have been identified in numerous hydro meteorological and geologic disasters. Usually, these adverse health outcomes have been attributed to structural collapses of residences, especially mobile homes, and to trees that have fallen on or near residences, places of employment, or on occupied motor vehicles (10, 12). In earthquake-related hazards occurring along coastal areas, deaths have been attributed to mechanical energy as a direct result of being crushed by building materials (6). As such, death may be characterized further as being by instantaneous, as from severe crushing; rapid, marked by asphyxia, hypovolemic shock, or hypothermia from environmental exposure; or delayed, marked by dehydration, hypothermia, hyperthermia, crush syndrome, among others (6).

Based on medical examiner and coroner reports and hospital-based surveillance, deaths and injuries during impact, particularly in hurricane events, have been associated with projectiles from unsecured objects, falls, and burns from unattended flames, improper use of gas generators, and trauma from escape attempts (10, 11).

In some instances, fatalities and injuries may result from a secondary disaster event accompanying the main disaster event, such as a tornado spawned from a hurricane (13). Through mechanisms of destructive winds, deaths in tornado activity have been attributed mainly to head trauma from flying debris or when thrown into stationary objects (6, 14).

2.2 Deaths and injuries from cleanup and reconstruction

Fatalities during cleanup and reconstruction are largely due to electrocution from the improper use of generators among occupational workers, lacerations from chainsaw injuries, trauma from structurally unsafe dwellings or weakened trees, and asphyxiation while entrapped under uprooted trees (6, 10). Deaths have also been observed from carbon monoxide poisoning in flood situations owing to the improper use of generators (11). Deaths also have been observed to occur when people sustain massive chest trauma after operating heavy equipment as such as a tractor, and myocardial infarctions while repairing damages and clearing debris, probably due to overexertion (12).

Common injuries consist mainly of wounds, lacerations and punctures, often from operating heavy equipment. In a study on hospital emergency department-based morbidity, the potential for hydrocarbon or bleach poisoning increased among children during the cleanup phase (15).

Wounds and insect stings accounted for 28 and 21 percent, respectively, of nonfatal hurricane-related cases in the aftermath of Hurricane Hugo in North Carolina in 1989 (16). In this event, the rate of cases diagnosed as wounds was observed to be 70.3 per 100,000 persons, and the rate of cases diagnosed as insect stings was 52.1 per 100,000 persons, occurring mostly as people were outdoors and engaged in cleanup activities. Although these health outcomes were documented inland, these conditions also may be possible along coastal areas. After Hurricane Opal struck Bay County, Florida in October 1995, the proportion of insect bites increased significantly from 0.2% to 1.7% among persons obtaining treatment in the emergency departments of two area hospitals (12). Likewise, increases in insect stings were reported in the aftermath of Hurricane Floyd in North Carolina in September 1999. The occurrence of insect stings and bites and stings highlights the vulnerability of hypersensitive people during cleanup and reconstruction.

Sprains, contusions, and fractures comprise the remaining spectrum of minor injuries usually sustained by an affected community. Hypothermia and dog bites also are reported to occur (11).

In earthquake events, dust from building damage and collapse can affect cleanup and recovery operations by causing eye and respiratory tract irritations (6). Aside from physically affecting air passages and lungs, dust may be contaminated with asbestos and other toxic materials such that it further poses an environmental hazard to rescue and cleanup personnel. Accounts of asbestos laden dust were reported after a devastating earthquake occurred in the cities of Kobe and Nishinomiya, Japan in 1995 (17). While building demolition work was in progress, a national environmental interest group detected a density of 250 asbestos fibers per liter of air around Kobe City, compared to 0.1 asbestos fibers per liter of air in Tokyo. Among the demolition workers, only one wore a protective mask.

2.3 Illnesses associated with debris and pollution

Illnesses may arise when water treatment and sewage disposal systems are disrupted, thereby affecting water quality and food safety. In these situations, the transmission of water-borne disease (e.g., enterotoxigenic *Escherichia coli*, *Shigella*, hepatitis A, leptospirosis, giardiasis) may exist, with outbreaks of such diseases expected in areas where the diseases of interest are endemic (6). Surveillance of these diseases often is recommended for local health departments when evaluating the impacts of floods and hurricanes.

In southeastern North Carolina in 1996, the risk of human illness from severe water quality problems was especially heightened after post hurricane flooding caused massive amounts of swamp water to be diverted into river channels, power failures of sewage treatment and pump stations diverting raw sewage into rivers, and the breaching of several swine waste lagoons diverting large quantities of concentrated organic waste into river systems (18). The short and long term anthropogenic impacts of these events have yet to be determined.

Illnesses also arise from the movement of displaced populations, who may be sequestered in close, temporary living quarters often with high population densities. In particular, respiratory illnesses have been documented in numerous disaster events, and may be exacerbated by exposures to extreme environmental temperatures and conditions during the period of displacement. Information from disease surveillance in free care sites after Hurricane Andrew struck South Dade County, Florida in 1992 indicates that proportional morbidity from respiratory illnesses, or the number of daily visits for each index condition divided by the number of total visits, increased during the five weeks post-hurricane. However, no outbreaks of infectious disease occurred (19). Similarly, outbreaks of self-limiting respiratory and gastrointestinal diseases were noted in shelters after Hurricane Floyd swept inland in North Carolina in 1999 (11). Asthma, in particular, increased significantly after this event, compared to a similar time period of the previous year.

Along the land-water interface of coastal areas, the abundance of enteric pathogenic indicator microbes, fecal coliform bacteria and *Escherichia coli*, is correlated with populations living on watersheds, the percentage of developed land within the watershed, and most strongly, with the percentage watershed-impervious surface coverage consisting of roofs, roads, driveways, sidewalks, and parking lots. Thus, the risk of potential waterborne disease is multiplied further in urbanizing coastal areas (20). Specific health risks have yet to be identified and characterized.

Flooding can increase the potential for environmental contamination by toxic chemicals, since inundated toxic waste sites can release harmful chemicals stored at ground level (21). In Honduras in 1998, floodwaters related to Hurricane Mitch were thought to have flushed unusually high levels of agricultural chemicals and pesticides into residential areas and rivers in area. Elevated levels of chlorinated pesticides and organophosphates were detected in the blood and urine of study adolescents, even though chlorinated pesticides had been banned in the country fifteen years ago. Data suggested that adolescent children faced ongoing exposures to pesticides (22).

2.4 Chronic health effects and birth defects

Long-term health effects have been observed after flooding. A cluster of deaths attributed to leukemia and lymphoma and a cluster of abnormal reproductive outcomes were reported to be related to a flood event in a river valley in western New York in 1972 (23). The illnesses and defects were attributed to high levels of natural background radiation in surface rock deposits in the area, radiation from a nearby nuclear processing plant, and radiation suspected to have originated in the new town water well. The flood was implicated as a possible etiologic agent for the deaths from leukemia and lymphoma.

The incidence of live-birth neural tube defects (spina bifida and encephalocele) increased in Jamaica after Hurricane Gilbert struck the island in 1988 (24). Rates of live-birth neural tube defects rose from 1.4 per 10,000 live births over 10 years to 5.0 per 10,000 live births in one quarter eleven to eighteen months after the hurricane event. The temporary increase was attributed to a diet comparatively low in folate during the periconceptional period, and coincided with a significant increase in folic acid deficiency in a vulnerable group of homozygous sickle cell patients. Destruction of the crops and livestock by the hurricane reportedly adversely affected the availability of fresh food rich in folate.

3. CONCLUSIONS AND RECOMMENDATIONS FOR MITIGATIVE STRATEGIES

Health hazards and their adverse effects in coastal areas should be further explored for their unique mechanisms leading deaths, injuries, and illnesses that can be prevented or reduced in further disaster events. Specific recommendations include the following:

1) Further studies should quantify risks, particularly among vulnerable subgroups in whom ill effects may be exacerbated: the poor; the elderly; persons with disabilities; women living alone; female-headed households; families with low ratios of adults to dependents; persons in congregate facilities; ethnic minorities; renters; transients; recent residents including immigrants; tourists; and the homeless (2).

2) Drowning continues to be a leading cause of death in flooding and hurricane events. Preventive messages and intervention strategies should be developed to target occupants of motor vehicles trapped in floodwaters, who seem to be a highly vulnerable group in recent disasters.

3) Health effects from hazards associated with water quality and the interface between land and water should be identified and characterized so that risks at the individual level can be quantified and addressed in prevention strategies for coastal communities.

4) Health effects from hazards of the built environment (i.e., integrity of structures) can be explored further to ascertain the safety of structures subject to coastal disasters. For example, injuries among occupants of mobile homes in low lying areas along coastlines may be quantified for their magnitude and severity as a public health problem. Interventions such as structural clips to "hurricane-proof" homes or earthquake-resistant design and construction techniques to strengthen structures may be evaluated using adverse health outcomes such as injury to occupants of the dwelling to ascertain their effectiveness in terms of preventing injury and achieving cost-effectiveness.

5) Hazards associated with the interface between the strong winds and the built environment should be identified for assessing the safety of vertical evacuation in heavily populated coastal zones.

6) Timely evacuation and accessibility to safe sheltering in face of various hazards should be explored for residents, workers, and occupants of coastal areas.

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