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Health Impacts of Sea-Level Rise

Cindy L. Parker

As a driver of coastal land use regulation, understanding the public health impacts of climate change and sea-level rise are key. That same understanding can help us prepare our infrastructure, public health resources, and hazard mitigation plans for the coming changes.—Ed.

There is no doubt that human-caused climate change is causing sea-level rise. In some places, such as along parts of the East Coast of the United States, sea-level rise is combining with land subsidence to worsen the problem. Climate change and sea-level rise are both considered “risk amplifiers” for health impacts, meaning that few health impacts are caused solely by climate change or sea-level rise. Instead, myriad health risks are made worse by different aspects of climate change. This article will focus on health impacts worsened by sea-level rise, by itself and in conjunction with other aspects of climate change.

The definition of the term “health,” as used in this article, is the same definition used by the World Health Organization: “Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.”¹ Thus, this article will address the more traditional health risks from sea-level rise, such as toxicity from water contamination and infectious disease, as well as some less traditional health impacts, which may pose even greater risks to the public’s health and well-being.

Although this article focuses on flooding and storm surge associated with sea-level rise, freshwater flooding can cause similar health impacts and occur both in coastal regions and inland.

IMPACTS OF FLOODS ON HEALTH

Floods can result when sea-level rise or storm surges inundate land with salt or brackish water. While inundation from sea-level rise may occur quite slowly, storm surge, often in concert with a hurricane, can cause devastating flooding in a short time.

These impacts are related. Relatively small amounts of sea-level rise can translate into large amounts of storm surge, depending on many factors including wind speeds and direction, tides, local geography and topography, and the existence of natural or artificial protective barriers. According to the National Oceanic and Atmospheric Administration, the large death tolls have historically been the result of a 10-foot or greater rise in storm surge.² As an example, scientists from the NASA Goddard Institute of Space Studies report that a Category 3 hurricane on a worst-case track could cause 25 feet (7.6 m) of storm surge at John F. Kennedy International Airport in New York City. With additional sea-level rise, that storm surge could be considerably higher.³ Hurricane Sandy, with Category 1 wind speeds, did an impressive amount of damage with just 12 to 14 feet of storm surge in the New York and New Jersey area in 2012.⁴

Floods can also result from fresh water, such as the heavy rains that fell on the Gulf Coast during Hurricane Katrina, from rivers overflowing their banks, from levees collapsing, or from dams giving way. Climate change is expected to expand floodplains all across the country, both coastal and inland.

When Hurricane Katrina slammed into the Gulf Coast in 2005 as a Category 3 hurricane, it wasn’t its high winds that caused the most damage to life or

property. It was the flooding. Floods can affect health in a variety of ways, such as from drowning and injuries; increasing the risk of infectious diseases caused by contaminated water supplies, insects, or mold; and by causing mental health repercussions. In addition, floods can cause health impacts from changing and compromising the social determinants of health. This is a term used to identify the importance of the physical and social environment on the health and well-being of people as they progress through life from birth to death. Extreme weather events such as storms and floods can be life-altering, for example, by removing or compromising infrastructure on which we rely, such as water and sewage treatment plants, emergency response systems, health care services, and transportation systems. Socioeconomic conditions can change dramatically as a result of a storm or flooding—and rarely for the better—from loss of jobs, health insurance, and housing. Access to food can be compromised through price hikes or shortages when crops are damaged and transportation is interrupted. All the research indicates that climate change will bring on conditions that will enhance the size, scope, and frequency of these events.

People get injured and killed during floods. During Hurricane Katrina and the flooding that occurred after the levees broke, almost 1,800 people in the Gulf Coast lost their lives, primarily from drowning. Seven years later, Hurricane Sandy caused 117 deaths in the United States in 2012. Injuries and deaths can also occur as residents attempt to rescue themselves and their belongings and when they return to their homes to clean up and repair the damage.

RISK TO INFRASTRUCTURE AND HEALTH

Hurricane Katrina demonstrated that, as a society, we are not very good at evacuating people. It is possible and even likely that, with better planning and practice, we could get better at evacuating people. But we can't evacuate infrastructure, and there are health risks from flooded infrastructure. We rely on these large-scale public systems, such as hospitals, clinics, pharmacies, water and sewage treatment plants, garbage disposal, emergency response systems, roads and transportation, telecommunications, grocery stores, schools, and even legal systems, to maintain our health and well-being. As sea levels rise, more and more of the critical infrastructure upon which we rely to keep us healthy and safe will be at risk, and this risk not only affects people living directly on a coastline but everyone who relies on infrastructure close to a coastline. Considering that about half of the U.S. population lives within 50 miles of a coastline, there is potential for many peoples' health to be adversely affected.^{5,6}

For example, for years after Hurricane Katrina struck New Orleans, the health care system was still reeling from a lack of physicians, a lack of hospital beds, insufficient numbers of allied health personnel like nurses and technicians, and a lack of nursing homes and rehabilitation centers for discharged patients who no longer needed to be in the hospital. Many physicians did not return after the hurricane. Of those who did, many then left again, particularly specialists, because the equipment and infrastructure they needed to practice their specialty was not available.⁷ Meanwhile, some parents living in the Federal Emergency Management Agency's trailers in Louisiana reported that their children had required repeated emergency room visits and had been hospitalized for severe asthmatic episodes because they couldn't get their children's asthma medications. Even some of those children who had seen physicians after the storm were not put back on their previous medications because their past medical histories could not be checked. Overall, compared

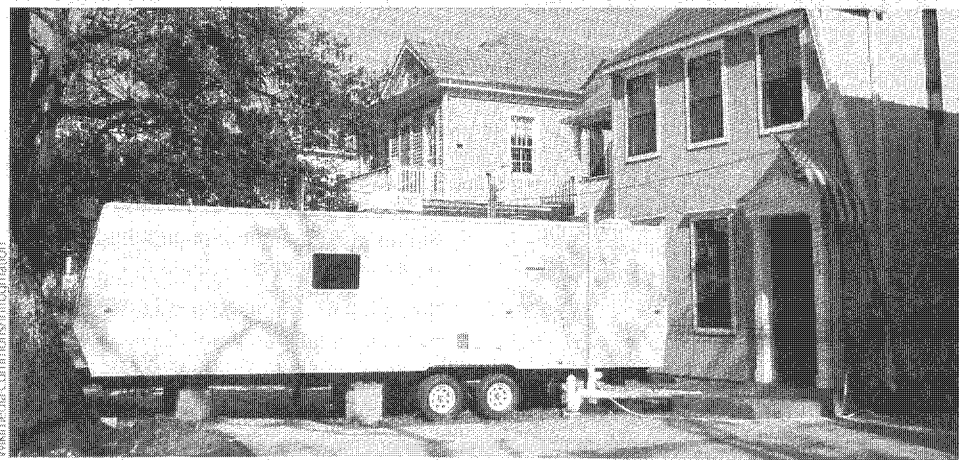
to national averages, these parents were three times more likely to report that their children's health was fair or poor.⁸ Health care providers' inability to access medical records lost or damaged by flooding was an additional barrier to good care.⁹ Moreover, many patients lost their jobs and therefore also lost their health insurance after the storm. Economists identified the loss of the health care infrastructure in New Orleans as a major barrier to economic revival.¹⁰

Even if flood victims survive the immediate danger of the flood, they're still at risk for more health problems. In the United States, rates of high blood pressure rose by 35 percent in affected Mississippi families after Hurricane Katrina, and half of the parents and 40 percent of the children living in Federal Emergency Management Agency trailers had at least one chronic medical condition, compared to a national average of about 13 percent.¹¹ Even years after experiencing a flood, survivors have higher rates of physical illnesses, such as diabetes, high blood pressure, and heart disease. Two studies in the United Kingdom found a 50 percent increase in deaths from these sorts of causes in flood survivors during the year after they experienced a flood.¹² A recent study found that for at least six years following Hurricane Katrina, there was a three-fold increase in the percentage of hospital admissions for heart attacks. They also found that the victims of the heart attacks had higher rates of smoking, a psychiatric diagnosis such as depression or anxiety, lack of health insurance, and unemployment, and concluded that

effects of chronic stress are likely contributing to the heart attacks.¹³

People's health may be compromised even more after a disaster if they become poorer as a result. Those who are already poor suffer the most: One of every two households with an annual income of less than \$10,000 before Hurricane Katrina lost all of their salaried jobs after the storm, while only one in six households with an annual income of more than \$20,000 before the storm lost their jobs thereafter. Moreover, children in coastal Mississippi were twice as likely to be uninsured after Hurricane Katrina, resulting in many parents unable to obtain care for their children.¹⁴ Hurricane Katrina showed us that storms, coupled with sea-level rise and inadequate flood management, result in people experiencing devastating alterations to their ways of life that can upend their psychological, as well as physical, balance.

While many people only have normal, short-term reactions of stress, grief, anger, sadness, anxiety, guilt, and poor sleep, extreme disaster experiences can lead to long-term post-traumatic stress—an illness that occurs when victims relive their traumatic experiences over and over in their minds, avoid anything that reminds them of the trauma they experienced, and remain persistently aroused or anxious.¹⁵ Other forms of anxiety, depression, family problems, difficulties at work, child misbehavior, poor academic functioning, a sense of lost identity, and a host of other symptoms also may occur as a result of these experiences.¹⁶ Moreover, people who have anxiety and



Flooded infrastructure compromised health care for victims in New Orleans.

depression before these climatic disasters are more likely to experience severe reactions in response to them.^{17,18}

The research on mental suffering after floods and other natural disasters is sobering. After Hurricane Katrina, one study showed that mental illness doubled.¹⁹ One year after Hurricane Katrina, children of affected families were four times more likely than before the storm to have a diagnosis of depression or anxiety and twice as likely to have behavioral problems.²⁰ And while often these psychological problems do diminish, they also can persist or be rekindled at the anniversary of the initial disaster.²¹

SEA-LEVEL RISE AND INFECTIOUS DISEASE

Diseases carried and spread by insects are expected to increase with climate change. For example, warmer temperatures allow mosquitoes to mature more quickly, and the viruses that they carry also mature more quickly. Warmer temperatures drive female mosquitoes to bite more frequently, making them more effective at spreading disease. Longer summers allow additional breeding cycles, adding to the risk of diseases carried by insects. Insects such as mosquitoes require standing water to lay eggs and for the larvae to mature to adulthood. While most mosquitoes responsible for spreading diseases to humans require freshwater for reproduction, there was evidence following the Indian Ocean tsunami in 2004 that these mosquitoes were able to adapt to the brackish and saline water that was pushed farther inland, and populations of mosquitoes expanded. Sea-level rise is expected to mimic some of these conditions, pushing more brackish and saline water farther into inland areas. Some evidence suggests that the main biological control, a bacteria bred to secrete a toxin that specifically kills mosquito larvae, is less effective in brackish or saline waters.²²

It is possible that the United States may again see more widespread diseases such as dengue fever (also known as “breakbone fever” because of the pain it causes), malaria, and other diseases carried by insects, espe-

cially mosquitoes, as global average surface temperatures increase from global climate change and rising sea levels. Perhaps the most worrisome disease, however, is the one that we don’t yet know about. Newly emerging or reemerging diseases can do a lot of damage before the experts can figure out what’s causing it and how to stop it. Climate change and resulting sea level may give some infectious diseases, especially those carried by insects, an advantage. A strong public health infrastructure is important to detect disease outbreaks early and get them under control as quickly as possible.

FLOODS, CONTAMINATION, AND DISEASE

The risk of contracting an infectious disease increases following a flood. As floodwaters wash over farms, they pick up manure, chemical fertilizers, and pesticides. As they wash over industrial sites, they pick up whatever chemicals have spilled onto the ground during normal operations and from the storm causing damage to storage tanks or machinery. And as they wash over towns and cities, they pick up gas and oil from the streets, garbage, toxins, bacteria and other germs, and everything else that is lying around. All of this floodwater, along with everything it is carrying, then washes into surface waters, such as lakes, rivers, and reservoirs, which supply much of the United States with its drinking water.

Water treatment plants are fairly decent at removing normal amounts of germs. When the water is dirtier than average, however, some of the germs are not removed or destroyed and end up in the drinking water that comes out of the tap, explaining why the majority of waterborne disease outbreaks occur after heavy rains. The most famous outbreak occurred in Milwaukee in 1993. The area around Milwaukee received very heavy rains prior to the outbreak. More than 400,000 people got sick with a germ called *cryptosporidium*, resulting in 54 deaths.²³ After Hurricane Katrina, there were more than a thousand cases of vomiting and diarrhea reported among evacuees relocated to Houston. The

culprit was determined to be norovirus, a virus often responsible for large outbreaks of diarrhea on cruise ships. Norovirus is particularly easy to pass from person to person and only a tiny amount of the virus can cause disease.²⁴ Fortunately, norovirus is rarely fatal. During an extreme weather event such as Katrina, flooding can contribute to a loss of electrical power and damage to pipelines, buildings, and machinery. That, in turn, can knock out water and sewage services and compromise residents’ ability to maintain good hygiene.

People directly exposed to floodwaters during and after Katrina came into contact with a variety of bacteria, including *vibrio*, which causes cholera. The form of *vibrio* that was most concerning following Katrina, however, does not cause cholera but is extremely deadly when it infects wounds. Hospitalization is required for 90 percent of people who get this infection, and 25 percent die from their infection.²⁵

Water treatment plants were never designed to remove chemical toxins, and these can also enter our drinking water. Even in low doses, many chemicals can cause harm to health in the short term and potentially increase risks of cancer later in life. Floodwaters washing over sites historically used for metal mining, for example, have been found to contain high concentrations of lead. The lead-contaminated water can be deposited into drinking water sources or the lead can settle out of the water into the soil of flooded areas. Humans are then exposed to the lead through breathing in contaminated soil dust and through ingesting contaminated drinking water, plants, or food animals that were fed plants raised in contaminated soil.²⁶ Lead is especially dangerous to children and developing fetuses, causing neurological problems that can result in reduced intelligence and behavioral problems. There is no “safe” level of lead.²⁷

FLOODS, MOLD, AND MORE

Flooding, hurricanes, and storms, made worse by rising sea levels, also cause moist environments, which can soak walls and floors in housing to create ideal environments for disease-causing

mold to grow. Some molds cause allergic reactions or infections, or secrete deadly toxins. Exposure to molds can cause symptoms that range from mild congestion and itchy eyes to shortness of breath and neurological trouble. Individuals who have respiratory conditions, such as asthma or chronic obstructive pulmonary disorder; who have immune systems that don't work well; who are pregnant; or are younger than 12 years old are at especially high risk and should avoid mold exposure.²⁸

After Hurricane Katrina, about half of all homes in the flooded areas were contaminated with mold, and many of those homes were heavily contaminated.²⁹ In addition to mold, flooded buildings, standing water, and damp environments that occur after floods and hurricanes also provide ideal living conditions for dust mites, which can make asthma worse, and bacteria, which can cause allergic reactions and lung infections. Standing water also promotes cockroaches and rodents, and many building materials contain toxic chemicals that can be released with prolonged moisture.

SALT WATER CONTAMINATION OF WELLS

One of the most damaging implications of sea level rise and resultant flooding is the potential for contaminated fresh water wells and aquifers. The health of a population relies on adequate supplies of clean, fresh water. In many coastal areas around the world, including the United States, water wells are shallow, and the aquifers that provide the water for those wells also are shallow. This occurs even in some areas where human settlements are located on high bluffs. Moreover, rising sea levels push saltwater farther into freshwater streams, rivers, and estuaries, potentially contaminating freshwater sources and harming protective riparian ecosystems.

EROSION

Rising seas combined with big storms and surges also contribute to the erosion and loss of coastal land, potentially

causing the forced evacuation of homes and businesses, loss of property, loss of property value, financial ruin, and mental stress. By 2060, one in four houses located within 500 feet of the shoreline in U.S. coastal communities could be lost to erosion, concluded a special nationwide study commissioned by the U.S. Federal Emergency Management Agency.³⁰ That means that 25 percent of families living close to a coastline would lose their homes and 100 percent of families living close to a coastline have to worry about what they would do if that were to happen. Could they keep their children safe? How much would be lost? Where would they go? Would they get enough money from the insurance, if they have insurance, to buy a house elsewhere? This kind of anxiety takes a toll on health.

Some insurance companies have responded to this economic risk by announcing that they would no longer offer home owners insurance to some coastal communities along the Eastern Seaboard and Gulf of Mexico. Following substantial losses in Florida and the Gulf Coast during the past few years, several insurance companies have raised their rates precipitously or dropped coverage altogether for businesses and residences in these areas.³¹ The inability to secure home owners insurance can prevent the sale of the home, which can compromise financial security, especially in retirement. Financial worries are one of the most common causes of mental stress and anxiety, which then take a toll on physical well-being.

It is possible, however, that some coastal areas could be made safer and protected, to varying degrees, from erosion and storm surge. Some scientists have estimated, for example, that if the Louisiana bayou between New Orleans and the Gulf had been intact rather than degraded for decades by human activity, storm surge from Hurricane Katrina could have been reduced considerably.³²

With climate change and sea-level rise expanding flood zones and increasing health risks for people living in or near potential flood areas, society must make some

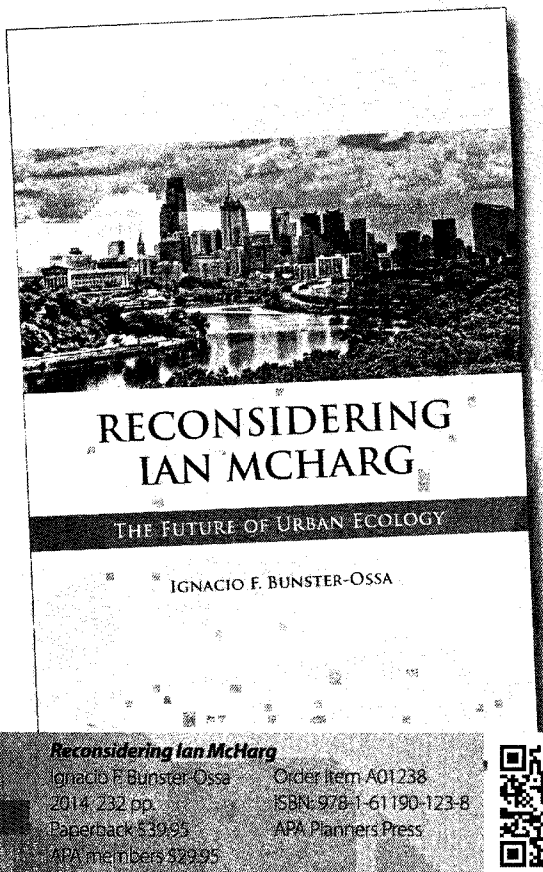
uncomfortable decisions about how to reduce risks, including voluntarily relocating people and infrastructure from high-risk areas. From a public health perspective, for undeveloped or underdeveloped areas at risk of flooding, it makes more sense to prevent further development in these areas. Failure to do so deliberately exposes people to potentially devastating—and largely preventable—risks to their health and well-being.

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