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Environmental exposures due to natural disasters

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Abstract

The environmental mobilization of contaminants by “natural disasters” is a subject of much interest; however, little has been done to address these concerns, especially in the developing world. Frequencies and predictability of events, both globally and regionally as well as the intensity, vary widely. It is clear that there are greater probabilities for mobilization of modern contaminants in sediments. Over the past 100 years of industrialization many chemicals are buried in riverine, estuarine and coastal sediments. There are a few studies, which have investigated this potential risk especially to human health. Studies that focus on extreme events need to determine the pre-existing baseline, determine the medium to long term fate and transport of contaminants and investigate aquatic and terrestrial pathways. Comprehensive studies are required to investigate the disease pathways and susceptibility for human health concerns.

Keywords

chemicals; economic cost; environmental contaminants; health effects; natural disasters

Introduction

The environmental mobilization of contaminants by “natural disasters” is a subject of much interest, however, little has been done to address these concerns, especially in the developing world. Frequencies and predictability of events, both globally and regionally as well as the intensity, vary widely. Vulnerability of people depends on whether they live in harms way in flood plains, on the coast, at or below sea level, or near streams or near areas of known contamination. Those people living closest to the source are most vulnerable. The intersection of natural disasters, contaminants and people is the subject of this paper. The coastal environment is becoming more vulnerable to damage from natural disasters. Sea-levels are rising, subsidence of land is increasing in some regions and decreasing in others. Upper ocean heat content is predicted to increase, atmospheric water content is increasing

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possible leading to more downpours, exacerbated flooding and general human misery. Coastal populations are increasing as people move closer to the coast increasing risk of greater damage. Also harmful algal bloom frequency, hypoxic or “dead zones” are becoming more prevalent and spills of various substances occur at regular frequency and variable intensity (1).

Disasters

Disasters occur all over the world at different magnitudes. Earthquakes, volcanic eruptions, landslides, tsunamis, wildfires, floods, extreme storms, tropical cyclones, tornados, dust storms are only some of the natural events that occur. Many are rapid onset disasters, others are more prolonged such as drought and climate change (2). They can occur all over the world at different frequencies and magnitudes. An example of this was the Tohoko earthquake in Japan, which became a cascading disaster as the earthquake caused damage and fires. The earthquake also created a massive tsunami which drowned thousands of people, and destroyed property and businesses. This caused the Fukushima nuclear plant to close down, spilling 1.2 million liters of water into the ocean and the release of contamination in the air, exposing humans, plants, animals and fish (3). The local fishery was closed to prevent further transfer to humans though ingestion of seafood. Two radioactive isotopes of iodine-131 with a halflife of 8 days and cesium-137 with a half-life of 30 years were released. Of the two it was clear that plant workers at the Fukushima power plant were of the highest risk from cesium-137. There were studies carried out on radioisotopes in migrating tuna but this risk was determined to be minimal. The secondary issue of this cascade was that many globally distributed companies, which were producing a wide array of components for technology in the automobile, computer and engineering industries quickly moved their companies to back-up facilities in Thailand. Unfortunately, these back-up systems were in the Chao Phraya river valley or flood plain and suffered from catastrophic floods in 2011. This globalized supply chain became a major loss for global companies as well as their insurers and reinsurers as their secondary emergency facilities flooded.

Trends of tropical cyclones

The trend of the frequency of tropical cyclones in both the Northern and Southern Hemispheres, is stagnant in numbers and in some cases decreased (Maue, 2016). At the same time the intensity of cyclones through the calculation of accumulated cyclone energy (ACE) is in a global lull. This fits well with recent studies (5, 6) and while there have not been any category 3–5 storms making landfall in the US for almost 10 years (7) (Figure 1) it is likely that a major storm event will occur in the future. People are moving closer to the coast with more property at risk. The perception of the increase in tropical cyclones due to climate change appears to be related to increasing monetary losses. For example, the Florida hurricane of 1926 had an estimated loss of \$47 million would now have an estimated loss of \$195 billion due to the immense increase in wealth concentrated in the area. The trend of acquiring property close to the coast and more people moving seaward puts more property and people and their belongings at risk (8). It is almost inconceivable that a small storm such as superstorm Sandy, which made landfall in 2015 in New York and New Jersey created an

estimated \$50 billion due primarily to making landfall in these coastal states at high tide with a very large storm surge. In 2013 alone, 13 events caused \$43 billion of insured losses.

Transformation of contaminants

There are a number of processes that act on debris from disasters, which have to be considered. There is dispersion, dilution, pulverization, oxidation and reduction reactions, condensation, evaporation and volatilization, photolysis, microbial degradation and sediment sequestration to name a few which all affect pathways of human exposure. These lead to many characterizations of contaminants into broad groups such as physical characteristics such as shape, size, mineralogy, etc., major and minor elements, organic contaminants such as polynuclear aromatic hydrocarbon (PAH), halocarbons, polychlorinated biphenyls (PCBs), etc., microbial characteristics (viruses, bacteria, pathogens), reactivity with the aqueous regime and bio-accessibility to organisms, etc. (2).

Public health outcomes of disasters

The public health outcomes can be obviously acute or chronic. The immediate effect on health such as fatalities and injury are easy to gauge. However, psychological effects as were seen during the Deep Water Horizon oil spill in the Gulf of Mexico are much harder to discern (9). For example, the loss of one or two jobs in a family had serious repercussions for communities in the Gulf of Mexico. Other public health outcomes range from exacerbation of chronic disease and stress, enhanced effect of infectious disease outbreaks particularly in developing countries, displaced communities and serious degradation of public health infrastructure. In extreme cases refugee camps provide a concentration and possible magnification of many of these issues. Health effects of volcanic eruptions are more biased towards pulmonary health concerns such as asthma and it has been shown that tropical cyclone destruction and power shortages can shut down scrubbers in power plants, which then release non-filtered contaminants thus causing more dust and pulmonary complaints. Floods, for example, have direct health effects such as drowning, however, hypothermia, injury from flood-borne debris, rainfall or erosion triggered land and rock slides, wind-related damage, falling trees or power lines and ignition of spilled fuels create havoc. Just like the other disasters there are long-term physical and psychological damage as well as exacerbation of chronic health conditions (2).

A few examples

In 2005, Hurricane Katrina caused direct damage to land due to the wind, storm surge and the failing of the levees leaving the residents of New Orleans in a toxic gumbo. Sewage systems broke down and contaminants were distributed all over the city. Unfortunately there were very few soil measurements made prior to the storm but lead was elevated in the downtown New Orleans area compared to the areas around it (10) (Figure 2). There are incidental reports that in some cases arsenic was elevated in some school playgrounds but in others was reduced after the storm. There is still more to learn. After Superstorm Sandy there were many contaminants and bacteria in the subways of New York, however, like many of these cases there was limited pre-disaster data with which to compare. The floods in

Colorado 2011, are another example where material destroyed by the floods did not make it downriver; these were either pulverized, diluted or buried with the floods. Mine tailings from the Jamestown mine were intermixed with the sediments and water and asphalt from roads was entrained into the sediment material. Water tanks, storage tanks and petroleum storage devices were swept up by the floods and distributed oil and other petroleum products to the floodwaters however, these were diluted due to the magnitude of the sedimentation. These events continue to happen as in August 2015, an error in mine tailing restoration lead to a soup of cadmium, arsenic, lead and aluminum being discharged into the Colorado River turning the river orange for a 100 miles.

How to prepare for the future?

There are some projects and programs, which are attempting to collect contemporary data to better understand what the risks of disasters are to human health. One of these is a program called Arkstorm for flooding in San Francisco Bay (11). All of the sewage treatment plants are mapped and contingency plans have been made to prevent the spread of bacteria, viruses, personal care contaminants and other pollutants. It is clear that there needs to be a well-planned response with good geochemistry to be able to reliably predict contamination impacts after these disasters. There is no question that sea-level rise will play an important role in the vulnerability of ecosystems and people living in coastal communities. Subsidence from such actions as groundwater extraction, mineral extraction, draining of land (compactions) and buildings and roads add weight. Levies and dam construction prevent recharge of ecosystems with new sediment thus creating a net loss in height. Coastal cities such as Houston, Venice and New Orleans in the US and in Asia, Tokyo, Osaka, Shanghai and Bangkok are examples, which have been affected and Jakarta and Manila will have problems in the future. Another issue is the predicted increase in upper ocean heat content, which has many consequences. The warmer the ocean becomes, the greater the evaporation from the sea surface and the greater the risk of large rainfall events. One such event occurred in Brisbane, Australia in 2010/2011, where the Wivenhoe dam almost overflowed and water had to be let out of the dam quickly, which caused serious flooding (12). Extreme precipitation in the US has increased and the bigger storms are getting bigger and the extreme storms account for an increasing fraction of total precipitation worldwide (13, 14). This evaporation from the ocean and related rain on land in late 2010 early 2011 actually caused global sea-level to stop rising for a short period of time. It is also clear that drainage systems in many major cities in China, UK and elsewhere have not been upgraded for years and cannot deal with these increased rain-rates. Flooding in Texas was so bad in May/June 2015 that most of the rivers overflowed and there were many fatalities due to flash floods, similar to those in Colorado in 2011. In India in August 2015, massive flooding was responsible for many fatalities. We know nothing about the mobilization and human health effects of contaminants during and after these events. Basically although it is apparent that these disasters have occurred and continue to occur however, we know little about the environmental and human health outcomes.

Conclusion

It is clear that there are greater probabilities for mobilization of modern contaminants in sediments. Over the past 100 years of industrialization many chemicals are buried in riverine, estuarine and coastal sediments. Examples are lead from leaded gasoline, the manufacture of a wide range of recalcitrant chemicals during the industrial age such as PCBs, dioxins, all exist in the deeper sediments. There are a few studies, which have investigated this potential risk especially to human health. Studies that focus on extreme events need to determine the pre-existing baseline, determine the medium to long-term fate and transport of contaminants and investigate aquatic and terrestrial pathways. Aquatic exposures can include dermal contact, accidental ingestion and seafood ingestions whereas terrestrial exposure pathways can come from soil ingestion, food ingestion and inhalation from re-suspended materials. Comprehensive studies are needed to investigate the exposure, toxicity and disease pathways, as well as susceptibility for human health concerns (11). Knap et al. (15) called for a network of ocean and human health programs which were funded, however, none focused on the problem of mobilization of contaminants to human health. It is time to change that.

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Figure 1. US hurricane drought. Each bar is related to the time in days of a Category 3–5 storm, making landfall in the US. The height of the bar reflects the time since the last major land-falling storm. The present period is the longest since 1900 without a significant storm (7).

Figure 2.
Mobilization of lead in sediments after Hurricane Katrina (10).