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Editorial

Resetting the bar: Establishing baselines for persistent contaminants after Hurricane Sandy in the coastal environments of New Jersey and New York, USA

1. Introduction

In the immediate aftermath of natural disasters, public health officials and other first responders engage in many activities to protect the public and ecosystems in the affected area. These activities include critical tasks designed to minimize adverse consequences resulting from chemical and microbial contaminant exposures, such as acute disease incidence and transmission. However, once these urgent priorities have been met and situations requiring immediate attention have been stabilized, questions regarding the potential longer term threats to humans and ecosystems associated with persistent contaminant exposures remain. Research conducted to address these questions is frequently challenged by the lack of available baseline contaminant information collected before the event for comparison and perspective. In addition, deployments of field crews and collection of environmental samples typically occur days, weeks, or months after the event. Consequently, during and in the aftermath of disasters, public health agencies commonly advise the public to disinfect water, avoid contact with disturbed infrastructure (such as sewer lines), and (or) refrain from use of recreational waters, with the general focus on acute health threats; however, the persisting effects of such releases on local recreational waters, fisheries, and other estuarine habitats are often undetermined.

Potential contaminant sources are prevalent in developed coastal areas and include combined sewer overflows; debris from buildings, automobiles, and boats; inundated infrastructure such as gas stations, landfills, chemical storage facilities, and hazardous waste sites; and saline water intrusion in estuaries and on shorelines. The vulnerability of nearshore environments to storm-derived contamination depends on factors associated with the storm (such as wind speed, precipitation, path, and timing) and the contaminant sources it disturbs. These drivers, which are often the basis of predictive models such as ARkStorm (Plumlee et al., 2015), are not commonly monitored together or within the context of the potential environmental health threats associated with long-term contaminant exposures after storms. Consequently, the requisite data for determination and (or) modeling of contaminant impacts effects resulting from large coastal storms are typically lacking or minimal. For example, contaminant (chemical and microbial) vulnerability of an estuary to a storm that generates large-scale interior flooding will differ from that of a storm that generates tidal surges.

Hurricane Sandy (commonly referred to informally as "Superstorm Sandy") made landfall in the United States (US) near Brigantine, New Jersey (NJ) on October 29, 2012 and was the second costliest hurricane to strike the US since 1900 (Blake et al., 2012). This hurricane was also noteworthy in that its path was highly unusual. Unlike most Atlantic hurricanes and their remnants, which generally follow a northerly track that roughly parallels the east coast of the United States, the northern advance of Sandy was impeded by the presence of a large high-pressure system over Canada, which caused the storm to veer to the west. This unusual track, in combination with spring tides, led to historic storm surges that breeched barrier islands and caused coastal flooding (in some cases as much as 5 km inland) throughout N J, New York (NY), and Connecticut, particularly within the NY metropolitan area. Although other Mid-Atlantic hurricanes and tropical storms—for example, Hurricane Irene (August 27–28, 2011)—have produced locally damaging storm surges, their regional effects are typically characterized by intense rainfall and subsequent riverine flooding.

In the aftermath of Hurricane Sandy, critical infrastructure throughout the region was compromised by storm damage and flooding, disrupting electrical service, receipt and refinement of petroleum, and natural gas distribution (U.S. Department of Energy, 2012). For weeks after Sandy made landfall, inundated and damaged wastewater treatment facilities in NJ and NY released an estimated 10.3 billion gallons of untreated and partially treated sewage to local rivers and bays (Kenward et al., 2013). As floodwaters receded and dewatering activities ensued, potentially contaminated water and sediments from inundated transportation tunnels and industries entered local waterways, with unknown environmental health consequences.

In response to this natural disaster, the U.S. Geological Survey (USGS) received supplemental appropriations from the Department of the Interior to support response, recovery, and rebuilding efforts. A science plan (Buxton et al., 2013) was designed to provide the critical scientific information necessary to inform management decisions to aid in the recovery of coastal communities and the preparation for future natural hazards. This plan was divided into five distinct themes based on impact types and information needs:

1. Coastal topography and bathymetry
2. Impacts to coastal beaches and barriers
3. Impacts of storm surge and estuarine and bay hydrology
4. Impacts on environmental quality and persisting contaminant exposures
5. Impacts to coastal ecosystems, habitats, and fish and wildlife

Results of studies conducted by the USGS team associated with the fourth theme, impacts on environmental quality and persisting contaminant exposures, are presented in this collection of papers.

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Together, these studies provide a broad examination of persistent contaminant occurrence and environmental health threats potentially associated with releases and mobilizations throughout the region most severely affected by Hurricane Sandy. In recognition of the challenges associated with the lack of baseline data, these papers document the transdisciplinary and often novel approaches taken to analyze sediment- and tissue-bound contaminants in estuaries and beaches throughout NJ and NY as part of the USGS response to this natural disaster. Sediment and tissue were collected because the contaminant signal captured in these environmental matrices is likely longer term than that found in water column samples. On the other hand, groundwater, which together with its associated contaminants moves slowly, was sampled in association with on-site wastewater treatment failures due to the storm. Sampling locations were selected to span a range of known or suspected storm-related effects; land use/land cover (such as degree of urbanization, public beaches, and sensitive ecosystems); history of contamination; and availability of pre-event data sets. Results of chemical analyses were used to evaluate the presence of regulated compounds (trace metals and persistent organic contaminants), as well as steroid hormones, other endocrine-disrupting compounds, and a suite of other chemicals associated with wastewater discharges, where failed infrastructure was known or suspected to have caused releases of untreated wastewater, or where pre-event data or other comparative information was available. Other approaches used to assess the contaminant effects of the storm included evaluations of sediment toxicity, histopathology, biological assays, and diatom community structure.

Collectively, these papers provide primary assessments of the presence of contaminants in sediments and tissue after Hurricane Sandy, identification of the likely sources of these contaminants, and limited comparisons of contaminant occurrence before and after the storm. The data collected during these studies establish a baseline that can be used to evaluate the effects of future hurricanes. Results also highlight novel approaches to monitoring the effects of future disasters, such as analyses of young-of-year (YOY) bluefish as sentinels of event-associated contaminant releases and use of remotely sensed data as indicators of contaminant presence. These findings and lessons learned are informing the design of a new multidisciplinary approach by USGS scientists that will describe procedures for prioritizing sampling locations on the basis of storm characteristics, locations of other monitoring networks, and contaminant vulnerability. Tools will include novel uses of biologically driven contaminant analysis, sentinels, and assays, as well as field procedures to be used for monitoring before and after coastal storms and for determining environmental health consequences.

2. Study design

The study area (Fig. 1) consists of bays and near-shore areas adjacent to lands in NJ and NY that were inundated by Hurricane Sandy. Centered on the harbor and bay area between NJ and NY, it extends about 240 km south from New York City (NYC) along the NJ shore to Cape May, and about 160 km east of NYC along the entire southern shore of Long Island to Peconic Bay.

Three major research activities were undertaken to evaluate the persistent contaminant risks due to Hurricane Sandy. A literature and historical data review was conducted to identify and utilize existing data and interpreted findings to define pre-Hurricane Sandy conditions. The methods used, literature search results, and data retrieval results for sediment chemistry and toxicity are described in Fischer et al. (2015), and tissue-bound contaminant data are reported in Smalling et al. (2015). Retrieved data (including all associated metadata) were collated in a relational data structure to facilitate comparisons with data generated during this study. Appropriately archived sediment samples from key locations within the study area were identified and, where available, analyzed to provide pre-Hurricane Sandy contaminant data for emerging contaminants (ECs) that are not typically measured in routine monitoring programs. These results were used by the Hurricane Sandy Theme 4 team and are documented in many of the articles in this special volume.

Reconnaissance sampling of estuaries and low-elevation coastal areas throughout NJ and NY was conducted to gain a regional perspective on contaminant occurrence in the sediment and biota in estuarine environments affected by Hurricane Sandy that would aid in evaluating potential chronic human and ecological health issues. Remote imagery and inundation mapping indicate that most, if not all, bays and estuaries along the NJ shore, the NY/NJ Harbor complex, and the southern shore of Long Island were affected by storm-surge or river floodwaters. Potential sampling sites in these bays and estuaries were identified on the basis of storm effects and the availability of pertinent historical sediment- and tissue-quality data to facilitate comparison of pre- and post-Sandy conditions. From this pool, sampling sites were selected to represent the broad range of land-use types and associated contaminant sources affected by the storm in order to accurately characterize its regional effects.

Targeted studies were conducted to discern the relative contributions from the variety of contaminant sources that were identified, document transport pathways from source to critical human and ecological receptors, and evaluate contaminant fate and uptake scenarios with potential for long-term ecological and human-health consequences. These studies expand on the regional reconnaissance by enhancing current understanding of the mechanisms by which storms and subsequent environmental processes can affect the health of human and ecological communities.

3. Regional reconnaissance

In consultation with other Federal agencies (U.S. Environmental Protection Agency [EPA] and National Oceanic and Atmospheric Administration [NOAA]); State agencies (NJ Department of Environmental Protection and NY State Department of Environmental Conservation); and municipal agencies (NYC Department of Environmental Protection, Suffolk County Department of Health Services, and Town of Hempstead), the USGS evaluated potential sampling locations and obtained information on contaminant spills and land cover that would assist in site selection. Many potential sampling sites in the bays and estuaries were identified on the basis of the presence of pertinent historical sediment-quality data. Other potential sampling sites were identified to characterize regional differences in contaminant patterns (for example, sewage spills). The selected sites reflect a broad range of affected land-cover types and their associated contaminant sources, and provide a representative distribution for assessment of regional and localized storm consequences.

Bed-sediment samples were collected from June to October 2013 from 167 estuarine sites throughout the study area (Fischer et al., 2015). Sampling locations were characterized by using geographic information to identify potential contaminant sources. Characterizations included land cover; locations and types of businesses (industrial, financial, and others); spills (sewage, chemical, and others); bulk storage facilities; effluent discharges within 2 km of the sampling point; and discharges within inundated and noninundated regions near the sampling location. Samples were collected using standardized protocols and analyzed for particle size; sediment toxicity; and concentrations of total organic carbon, metals and trace elements, semivolatile organic compounds, wastewater compounds, and hormones. Samples were also screened using X-ray fluorescence, Fourier transform infrared spectroscopy, and X-ray diffraction. In addition, bioassays for endocrine disruptors and protein phosphatase 2A inhibition were conducted.

Young-of-year (YOY) *Pomatomus saltatrix* (bluefish) and resident *Mytilus edulis* and *Geukensia demissa* (mussel) tissue samples were collected from August 2013 to April 2014 from 20 estuarine sites distributed throughout the study area (Smalling et al., 2015). YOY