Destruction of the World Trade Center Towers Lessons Learned from an Environmental Health Disaster

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Abstract

The assault and subsequent collapse of the World Trade Center towers in New York City on September 11, 2001 (9/11), released more than a million tons of debris and dust into the surrounding area, engulfing rescue workers as they rushed to aid those who worked in the towers, and the thousands of nearby civilians and children who were forced to flee. In December 2015, almost 15 years after the attack, and 5 years after first enactment, Congress reauthorized the James Zadroga 9/11 Health and Compensation Act, a law designed to respond to the adverse health effects of the disaster. This reauthorization affords an opportunity to review human inhalation exposure science in relation to the World Trade Center collapse. In this Special Article, we compile observations regarding the collective medical response to the environmental health disaster with a focus on efforts to address the

adverse health effects experienced by nearby community members including local residents and workers. We also analyze approaches to understanding the potential for health risk, characterization of hazardous materials, identification of populations at risk, and shortfalls in the medical response on behalf of the local community. Our overarching goal is to communicate lessons learned from the World Trade Center experience that may be applicable to communities affected by future environmental health disasters. The World Trade Center story demonstrates that communities lacking advocacy and preexisting health infrastructures are uniquely vulnerable to health disasters. Medical and public health personnel need to compensate for these vulnerabilities to mitigate long-term illness and suffering.

Keywords: World Trade Center; disaster medicine; environmental health; inhalation exposure

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The airborne assault and subsequent collapse of the World Trade Center (WTC) towers on September 11, 2001 (9/11) released more than a million tons of debris and dust into the surrounding area (1), engulfing rescue workers as they rushed to aid those in the towers and the thousands of civilians and children who were forced to flee the disaster impact area. Almost 15 years after the attack and 5 years after initial enactment, Congress reauthorized the James Zadroga 9/11 Health and Compensation Act (Zadroga Act), designed to respond to the health effects of the

disaster. The reauthorization of the Zadroga Act affords us a timely opportunity to review our collective response to all populations affected by the environmental disaster of 9/11 to better understand how to reduce harm from future catastrophic environmental events. We review the history and reasons behind creation of the Zadroga Act in the context of concepts of human exposure science with a focus on the experience of the local community.

Human exposure science is defined as “the study of human contact with chemical,

physical, or biological agents occurring in their environments, and advances knowledge of the mechanisms and dynamics of events either causing or preventing adverse human health outcomes” (2, 3). Basic questions in the setting of a potential environmental disaster include the following: Is there the possibility of a health risk? What are the hazardous materials that might cause injurious exposures in a potential disaster? What are the populations at risk? What mitigations and treatments may be needed? We argue that reviewing these

basic questions in the context of this past event teaches us that in the setting of an environmental disaster, we need to adapt exposure science to pose these questions rapidly and for all populations with exposure. We also need to integrate this concept of disaster exposure science with disaster epidemiology to improve our ability to mitigate long-term illness and suffering.

Potential for Health Risk

On September 11, 2001, southern Manhattan was a teeming financial and residential hub, with hundreds of thousands of local workers, residents, commuters, tourists, and schoolchildren. In addition to the responders rushing to the damaged site, many of these community members in or around the site were heavily immersed in scattered debris and massive clouds of pulverized dust (dust clouds) created by the collapsing buildings on 9/11 (4, 5). The shock and chaos following the event delayed careful consideration of potential health risk to the responders (firefighters, police, and volunteers), and even more so to the larger, less visible local community of workers and residents.

Only days after the event, and before any test of indoor air quality had been conducted by any government entity, Christine Todd Whitman, the U.S. Environmental Protection Agency (EPA) Administrator, reassured the public: “their air is safe to breathe [*sic*] and their water is safe to drink. ...New Yorkers...need not be concerned about environmental issues as they return to their homes and workplaces” (EPA press release, September 18, 2001) (6). Then New York City (NYC) Mayor Rudolph Giuliani exhorted civilians to do their patriotic duty and return to normal activities in southern Manhattan.

Returning to their workplaces and homes, many 1 week after the event, these men, women and children exposed themselves to resuspended debris from the 1.2 million tons of pulverized construction material that had covered the streets, parks, commercial buildings, schools, and apartment buildings, and to the persistent acrid odor from fumes from fires that burned for months (1, 7–9). Because the area was not declared a toxic waste site, protective rules were not implemented, and cleanup of the dust that permeated every area

of southern Manhattan and sections of Brooklyn was uncoordinated and unregulated. After denying the possibility of hazardous risk, the EPA relegated to the City of New York the responsibility for indoor air quality. This responsibility was, in turn, delegated to individual building owners or tenants. The City of New York recommendations for building reoccupation included recommendations for residents to use a wet mop (10). EPA assurances allowed for the denial of insurance payments to landlords, tenants, and residents to help in the cleaning. Thus the local community was at potential health risk from chronic exposures to airborne fumes and dust derived from continued burning or agitation of the debris scattered by the initial collapse.

Hazardous Materials and Exposures

A number of factors complicated our understanding of the hazardous materials produced by the destruction of the WTC towers. Initial studies of the toxicology of the airborne and settled dusts were limited by restricted access to the areas surrounding the disaster site and the destruction of all preexisting local ambient air monitors. In addition, there were no health-based clearance values for many of the toxins including the alkaline cement and vitreous fibers, or the complex chemical mixtures contained in the dust and fumes. Despite these issues, preliminary toxicology information was presented at a symposium at Pace University (New York, NY) in October 2001. Thus, although only incomplete information about hazardous materials was available early on, the risk to the community of exposure to these toxins was known within the first year of the event, and biological plausibility for adverse health effects was apparent (11).

The complexity of the WTC particulate components included the massive level of exposure to pulverized particulates from the collapsing buildings, the chemical transformations by high-temperature combustion, the subsequent resuspension of particles into the air in urban spaces, and the continued release of fumes from burning buildings. These multiple potential health hazards complicated the understanding of potential toxicity for the community, as well as responder populations (9).

We now know from analyses of locally collected settled dust samples performed by university-based Environmental Health Sciences research centers funded by the National Institute of Environmental Health Sciences (Research Triangle Park, NC), that indoor and outdoor settled dusts were a mixture of building debris and combustion products (mass median aerodynamic diameter, 23 μm), a blended mixture of concrete, gypsum, and synthetic vitreous fibers, with metals, radionuclides, ionic species, and asbestos (1, 3, 8). Organic analyses revealed polycyclic aromatic hydrocarbons, polychlorinated biphenyls, and other hydrocarbons (1, 8, 12, 13). The extreme caustic component of the WTC dusts, with a basic pH of 9–11, added an irritant dimensionality to their biological effects (1). Importantly, the dust was unusually aerosolizable, with a propensity to aerosolize that was 10–10,000 times more than that of ordinary office building surface dust, allowing for easy resuspension by gusts of air or mechanical disturbance and recontamination from unremediated sites (1, 9).

Occupational exposures for the responders are now characterized in terms of time periods of exposure (3). For those in the community, we now understand that there was potential risk from both acute exposures to the debris and dust clouds of 9/11 as well as chronic exposures (5, 14).

Populations at Risk

Because the federal government declared the area a safe environment soon after the building collapse, there was no recognized need to provide health surveillance to identify populations at risk. It took enormous efforts by labor and community advocacy groups, working with academic medical centers, public hospitals, local politicians, and news media reporters, to obtain any health surveillance at all. Firefighters, police officers, construction workers, and utility workers had rushed to the disaster area to save lives and aid the recovery operation. These groups, aided by their labor organizations and unions—and in the case of the New York City Fire Department, by a well-organized preexisting medical system—articulated the potential for health risk and the need for health surveillance. After months of growing demands for action and for a federal

response, a federally funded screening program, only for responders, was initiated in July 2002 (15, 16).

The local community included the many people nearby who had been enveloped by the dense dust clouds of the collapsing buildings; the workers who returned to their offices and stores through streets covered by resuspended dust and reeking of fumes; those who cleaned the surrounding area after the disaster; students enrolled in local schools; and the residents who returned to apartments coated with dust. Implementation of health surveillance programs for this community population lagged behind that for rescue workers and responders. The federal and local government failure to recognize the risk for these populations, and the political sensitivity and financial implications of recognizing that the risk was shared among such a large and heterogeneous group of people, delayed a comprehensive, federally funded surveillance program. Established national advocacy organizations were reluctant to contest the safety assurances issued by government agencies. Local advocacy groups were small, lacked expertise, and represented diverse issues. Over time, these local groups formed networks and collaborations, creating larger coalitions with increased influence and the ability to work in conjunction with national organizations, labor, elected officials, and academic institutions.

In the early years after the 9/11 attacks, the efforts to study health effects in community populations were ad hoc, disjointed, and small. Funded as a research study by the U.S. Centers for Disease Control and Prevention (CDC, Atlanta, GA), New York University/Bellevue Hospital (New York, NY), in partnership with the New York State Department of Health and a coalition of community groups, completed a study of local residents within the first 2 years. Performed in English, Spanish, and Chinese (Mandarin and Cantonese), the study required extensive fieldwork as the postal service was barely functioning. Despite these barriers, 2,812 residents completed surveys. Increased rates of new-onset upper and lower respiratory health symptoms were reported in the local residential population (17–19).

Funded by the CDC, the NYC Department of Health and Mental Hygiene subsequently created the WTC Health Registry and conducted their first survey in 2003, confirming these respiratory findings

and reporting additional health findings including dose–response associations and ongoing epidemiological studies, which included both responders and community members (5, 14, 20–22). Studies of medical illness in children were even more limited and subject to delay. Nevertheless, studies published by the WTC Health Registry investigators and others reported clearly increased asthma rates in children (23–25). All these studies documented that community members, as well as responders and rescue workers, were at-risk populations for adverse health effects.

Injury Mitigation and Treatment

Because the U.S. federal government declared the area around Ground Zero to be a safe environment, there was no recognized need to provide targeted medical treatment. The federally funded screening program for responders initially did not offer treatment. Private philanthropic organizations filled part of this gap. After years of demands put forth by labor groups and the New York Congressional Delegation, a federal program for treatment of WTC-related health effects was funded in 2006 for firefighters, rescue workers, and responders (15, 16). These programs documented adverse upper and lower respiratory and gastrointestinal health effects and an emerging excess incidence of cancer, as well as a high prevalence of mental health conditions consistent with posttraumatic stress disorder, depression, and anxiety in the responder population (26–30).

Treatment programs for community members were even further delayed. The asthma clinic of Bellevue Hospital, a New York City public hospital, launched a small, unfunded community treatment program at the behest of community organizations. This served a few hundred patients until the program was expanded through a grant from the American Red Cross, enabling thousands more to enroll. In 2006 the program was funded by the City of New York. Seven years after the attack, in 2008, funding was first received from the U.S. federal government through a grant aimed at providing treatment for people in the community. Patients enrolled in this community program reported symptoms similar to those described by disaster responders (31).

In 2010, when Congress first passed the James Zadroga 9/11 Health and Compensation Act, there was considerable political resistance to include exposed individuals in the community. Final inclusion of these people in the law came with conditions and restrictions. There was an assumption among many that the dust and fume exposure of the community members was less than that of the responders, and thus they were not at risk. In addition, there was great fear of the sheer number of potentially ill community residents, and worry that any treatment program would be too costly. Whether community members would be included remained a question throughout the development of the legislation, and it took the concerted efforts of community groups, labor, and local politicians to get community members written into the bill; their coverage differed from that of the responders.

The Zadroga Act created a World Trade Center Health Program (WTCHP) with Centers of Excellence with expertise in screening, monitoring, and providing comprehensive care for “Responders” and members of the community (“Survivors”) with WTC-related or associated conditions. The clinical services provided by the Centers for Excellence are carefully monitored, with contractors hired to oversee the programs and to prevent waste, fraud, and abuse. Each enrolled individual undergoes careful scrutiny to confirm WTC exposure. Before enrollment, applicants must be checked against the U.S. federal government Terrorist Watchlist.

To qualify for treatment, every medical or mental health condition must be “certified,” based on a physician’s attestation that the WTC exposure caused, contributed to, or aggravated the specific condition. For Responders, routine disease surveillance (monitoring) as well as treatment for certified conditions is provided. For Survivors, monitoring is performed only after the government has accepted enrollment with the presence of a “certified condition.” For Responders, disease surveillance and treatment are provided free of cost. For Survivors, the WTCHP is the secondary payer; personal insurance is billed first. As of August 2015, more than 62,700 Responders were enrolled for surveillance, more than 24,000 with a certified condition for treatment. As of that date, 8,475 Survivors were enrolled for treatment only.

What We Have Learned about Health Effects

Studies on the responder and community populations, including many derived from the WTC Health Program, the New York City Department of Health WTC Health Registry, and particularly the New York Fire Department with their years of pre-9/11 health information on first responders and a rapidly implemented surveillance program, provide invaluable information about health effects.

We now know that concentrations of fine, coarse, and supercoarse particles released in the disaster had potential for deposition on the skin, in the nasal passages, conductive airways and alveoli, and gastrointestinal tract, causing both physical and chemical irritation. Findings of persistent large particles in sputum, bronchoalveolar lavage, and lung biopsies suggest overload of normal defense mechanisms (32–35).

We now know that thousands of community members as well as responders suffer from chronic aerodigestive disorders including sinusitis, asthma-like illnesses, interstitial lung diseases, and gastroesophageal reflux that began or were aggravated by 9/11 exposures (5, 9, 14, 36).

We now understand that postdisaster mental health issues in adults and children were common and, importantly, also often chronic, including symptoms of posttraumatic stress disorder, anxiety, and depression related not only to the immediate trauma, but also to the longer-term recovery and rebuilding efforts and medical illnesses (16, 37–43). Comorbidity of mental and physical health issues compounds complexity of diagnosis and management.

We are now learning of increased hematological cancers and solid tumor rates in exposed populations (36).

The difficulties in precisely defining the population of community members who were at risk for health effects attributable to the disaster, the absence of baseline information about pre-9/11 health status, and the absence of a clinical surveillance program in the community, make it difficult to confirm causality. As a result, conclusions regarding attribution of health impairments to the WTC disaster are continually open to challenge. The WTC Health Program “Survivor” Center

of Excellence and the NYC Department of Health WTC Health Registry, major sources of data on this population, each has known limitations. Despite these limitations, they now have shown beyond argument that the nearby civilian population is at ongoing medical and mental health risk. Moreover, the community population, often more physically vulnerable than the responders, untrained in disaster response, with economic losses from the closing of businesses and loss of jobs, may be even more susceptible to medical and mental health illness than those trained in disaster response.

Comparison with Recent Environmental Disasters

How does the WTC disaster compare with other environmental catastrophes, such as those that affected Fukushima, Chernobyl, and Bhopal? A detailed comparison is far beyond the scope of this Perspective. However, we can identify several patterns in medical responses shared by these events, as well as several important differences.

The WTC disaster struck the heart of a wealthy Western city, whereas the Chernobyl disaster unfolded in a relatively remote province of a state-controlled economy, and the Bhopal disaster occurred in a deeply impoverished part of a then-underdeveloped nation. Despite these differences, responses were inadequate in all situations. After the WTC disaster, there were questions about whether there were health consequences for those who had been exposed. By contrast, in the chemical disaster in Bhopal of 1984, the Chernobyl nuclear power plant disaster in the Ukraine in 1986, and the Fukushima Daiichi nuclear power plant disaster in Japan in 2011, there was no such uncertainty. The Bhopal disaster resulted from a 27-ton gas leak of methyl isocyanate (44–48). The nuclear reactor accident in Chernobyl released radioactive isotopes including ^{131}I , ^{137}Cs , ^{90}Sr , and ^{239}Pu and the Fukushima Daiichi nuclear power plant disaster released volatile ^{131}I and ^{134}Cs (49). The complexity of the WTC particulate components and the difficulties in identifying the components delayed recognition of the toxic exposure to the community as well as responder populations (9).

Beyond these enormous social and scientific differences, certain commonalities remain. Each of these disasters exposed large civilian as well as rescue and recovery

populations to toxic substances. The Bhopal disaster exposed more than 500,000 people in nearby residential areas, with the death of 10,000 people (44–47). The plume from Chernobyl contaminated an area of more than 200,000 km² (50). Although the dust plume from the WTC disaster was smaller, the WTC disaster occurred in a densely populated area, with more than 410,000 individuals at risk for exposure (5).

Whether in an underresourced area such as Bhopal or the Ukraine, or in a modern metropolis, each of these disasters was associated with delays in risk mitigation, health surveillance, and/or treatment for civilian populations. Initial epidemiological data collection started in 1986 in Bhopal, with the Indian Council of Medical Research New Delhi (51). A Supreme Court judgment recognized the rights of the survivors and the need for health care provision only in 2012 (51, 52). After Chernobyl, mitigation measures with distribution of potassium iodide pills were implemented early, but incompletely. Health surveillance using “direct thyroid measurements” were performed on 350,000 individuals (50). Food and water measurements and restrictions, and mass evacuations, were put in place after both the Chernobyl and Fukushima disasters (50, 53, 54). However, radiation doses were not fully quantified, leading to uncertainty about exposures and the size of the population in need of monitoring or evacuation.

Each disaster was associated with high rates of psychological distress and varying levels of response by local mental health resources. The Fukushima nuclear disaster occurred after an earthquake and tsunami, with massive loss of life, and in the historical context of the atomic bombing of Hiroshima and Nagasaki (55). The Chernobyl disaster was associated with mental health symptoms, which were often chronic and associated with medically unexplained physical symptoms (50, 56). Although the Bhopal disaster was the first disaster in India to be studied systematically for mental health effects, the mental health needs of survivors of the Bhopal disaster were often denied. There was an 8-week delay before any mental health professionals were involved because none of the medical colleges in the area had a single psychiatrist on staff (52). The importance of recognizing potential health effects in children was identified in the Fukushima

and Chernobyl disasters (57). Limited studies have been performed in children exposed to WTC dust and fumes.

There are important commonalities affecting the implementation of surveillance and treatment of exposed populations following these disasters. The nature of such disasters makes planning for the study of health effects difficult, particularly in the design of epidemiological studies for mobile and diverse populations. In each of these disasters as well, the nation's political processes resulted in barriers to recognizing adverse health effects, delaying the implementation of standard environmental and occupational safety measures. The WTC area was considered "safe." In Japan, the standard System for Prediction for Environmental Emergency Dose Information that predicts the spread of radioactive substances was not used in the evacuation scheme, and the government modified the radiation safety standard for children at schools (57).

Lessons Learned for Future Disasters

The widespread failure to recognize and act on the tenets of environmental exposure science after the WTC disaster reduced our ability to mitigate adverse health effects for all populations exposed to the massive environmental disaster and to provide timely disease surveillance and treatment. We have learned from the history of community advocacy after 9/11 that a population without an organized community health infrastructure

such as that available to the firefighters, or preexisting advocacy capacity, such as that of organized labor, is less likely to receive recognition and surveillance as an at-risk group. Importantly, these local civilian populations include the vulnerable: the elderly, pregnant women, those with preexisting illness, and children, who are more at risk than professional responders, and at even lower exposure doses.

Recommendations for management of occupational exposures to future environmental disasters, which may prevent excessive exposure and consequent health effects, have been suggested (58). Additional recommendations for civilian populations are needed and include the following:

1. In environmental disasters, medical and public health personnel have a responsibility to compensate for the absence of preexisting institutionalized community advocacy groups by themselves advocating for, and involving, the community.
2. There needs to be a low threshold for the assumption of potential for health risk in the setting of potentially toxic environmental exposures. This is supported by acknowledgments by leading toxicologists about their inability to foresee the health impacts after 9/11 (9).
3. Medical and public health personnel need to implement timely health surveillance even before definitive toxicological measurements can be made, particularly because these measurements may not be feasible

during a disaster and may not be fully predictive of risk.

4. Surveillance should begin for biologically plausible health effects even before definitive health effects can be identified—especially because recognition of these outcomes may be delayed.
5. We must be realistic in assuming that political leaders in the future, facing new large-scale disasters, may be deterred from prompt action by the prospect of enormous financial costs and other political factors, and that a rigorous scientific response will always be needed to serve as a counterweight.

At the time of our next environmental health disaster, whether natural or human-made, we must implement concepts of human disaster exposure science and disaster epidemiology and we must rapidly assess risk to mitigate exposures and illness for all populations. We cannot let the lessons of our WTC experience go to waste. ■

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