CHAPTER 8

THE MEDICAL RESPONSE TO AN ENVIRONMENTAL DISASTER

Lessons from the World Trade Center Attacks

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LEARNING OBJECTIVES

- To understand how the government responded to environmental health risks immediately after the World Trade Center disaster
- To become familiar with how the government disseminated information and dictated cleanup of affected areas
- To understand exposure risk research and funding related to the WTC disaster
- To become familiar with the long-term health effects of exposure to WTC disaster materials

The September 11, 2001, terrorist attacks on the World Trade Center (WTC) in New York City resulted in collapse of the towers, generated a thick plume of dust and fumes that wafted across Lower Manhattan and Brooklyn, ignited fires that smoldered for months, and deposited more than one million tons of debris in one of the most densely populated and vitally important commercial districts in the world. In addition to the event's devastating personal, emotional, political, and economic consequences for New York City and the nation, the tragedy was an unprecedented and unanticipated environmental disaster. The scale of the environmental impact—both in terms of quantity and complexity of pollutants released and the size and diversity of populations at risk for adverse health effects—made the emergency response in the immediate aftermath of the attack exceedingly difficult.

Balancing the need for search and rescue operations, a criminal investigation of the cause of the disaster, restoring function to the financial district, and ensuring the safety of the residents and workers in the area was a complex task that fell upon multiple local and federal agencies. Criticism of the actions of the Environmental Protection Agency (EPA), **National Institute for Occupational Safety and Health (NIOSH)**, Occupational Safety and Health Administration (OSHA), the New York State Department of Environmental Conservation (DEC), and the many other government agencies present during the aftermath has been intense. It has become common knowledge that personal protective equipment was underutilized by rescue and recovery and cleanup workers. Many people focus on the air quality assessment by the EPA and the famous statement made by its director at the time, Christie Todd Whitman: "The air is safe to breathe, and the water is safe to drink." Reassured by the words of a well-known public figure, many area workers and residents returned to their homes and businesses with a sense that the danger had passed. Subsequently, the shortcomings of the agencies responsible for advising residents and workers on how to clean the debris may have needlessly increased the exposure and health risks of these individuals.

Certainly, the magnitude of the situation could never have been anticipated by any of these agencies, and, in fact, it could be suggested that each individual agency was able to achieve its particular mission with some success given the circumstances. Unfortunately, the actions of each agency were overlaid by political concerns and were never synthesized into a global assessment of the situation at Ground Zero (GZ) to guide health regulations and protect responders, workers, and the public. Furthermore, one might imagine that public health departments might have stepped in early on; however, the reality is that health departments have expertise in the domains of preventive medicine and infectious diseases, but little to no experience in acute environmental exposures. The

lack of a single authority, coupled with an enormous amount of political pressure to allow life in Lower Manhattan to resume, is likely the real reason that many warning signals of potential health threats were ignored.

This chapter focuses on the role of the medical and scientific community in the days, months, and years after 9/11 in elucidating the characteristics and toxicity of WTC dust and in caring for individuals with adverse health effects related to 9/11 exposures. We describe the accumulated knowledge on the characteristics and toxicity of WTC dust. We then follow a loose chronology to tell the story of how our understanding of WTC health effects emerged from single centers and grew through partnerships among medical, government, philanthropic, and community organizations. Finally, we discuss lessons learned from the WTC experience for future disasters and for environmental health in general.

This chapter was completed before the signing of H.R. 847, the "James Zadroga 9/11 Health and Compensation Act of 2010" on January 6, 2011, by President Barack H. Obama. This law, a result of continued efforts by rescue and recovery workers, community members, medical personnel, organized labor, and persistent congressional and senate members, puts into place a screening, monitoring and treatment program for adverse medical and mental health effects for rescue and recovery workers as well as community members. The hopes for this compromise bill are that funding will now be in place for continued health monitoring and treatment of populations at risk for adverse health outcomes. The fears are that onerous reporting requirements, rigid restrictions, and interesting additions (the government requires the name of each patient to ensure that they are not on the terrorist watch list), will provide barriers to care. Regardless, the signing of this bill, nearly ten years after the event, represents the culmination of combined efforts from diverse groups to move the federal government to provide an appropriate health response to an environmental disaster with wide ramifications.

Immediate Response to Environmental Exposure

Governmental agencies provided early reassurance about the components of the WTC dust as reports came in from an assortment of federally monitored sites.[1] Residents, rescue workers, and local workers were told that it was safe to go back to work one week after the event. The EPA did not declare Ground Zero a hazardous waste site or a Superfund site, thus allowing for reduced protection requirements for workers and diminishing the pressure for building owners to remediate their buildings. In addition, the EPA

denied that it had legal responsibility for assessing or addressing indoor environmental contamination, thus leaving the task in the hands of New York City agencies. Ultimately, no governmental agency took responsibility for indoor spaces. Indoor environmental testing and remediation of common spaces was up to the building owners, and commercial and residential tenants were left to contend with their private spaces. Technical advice provided by the federal and city government agencies was incomplete and incorrect; none of the agencies sought outside help from academic or private sources with expertise in the areas in which they were lacking information. In 2002, almost one year after the event, the EPA began a "Test and Clean Program" that was nonmandatory and limited to residences.[1,2] This program, targeted to a limited area, allowed for either testing or cleaning followed by testing. Only 18% of eligible apartments were either cleaned or tested, and no commercial or institutional buildings in Lower Manhattan were included.[2]

Analysis of World Trade Center Dust

As it rapidly became evident that the risks imparted by the 9/11 event would require immediate and extensive study, the **National Institutes of Environmental Health Science (NIEHS)** expanded funding of four existing Environmental Health Science Core Centers (New York University; Columbia University; University of Medicine/Dentistry in New Jersey, R. W. Johnson Medical School, [RWJ-UMDNJ]; and Johns Hopkins Center in Urban Environmental Health) to perform exposure assessments, characterize debris, and monitor health effects. These research centers, funded for toxicologic and environmental studies in adult and pediatric populations, had a wealth of expertise in toxicology and epidemiologic studies. Additional funding was rapidly provided to these centers to expand their mandate, and investigators with a range of expertise were recruited to develop and implement studies using air sampling, toxicologic assessment, and human outcomes. These centers, working as an NIEHS consortium distinct from governmental agencies, subsequently provided a wealth of information about specific hazards posed by the dust and helped describe some of the resultant symptoms and syndromes that became widely recognized in affected populations.

Prediction of health effects was exceedingly complex for many reasons. There was a tremendous diversity of materials contained in the office buildings that made up the WTC site. By some estimates, the buildings contained 300–400 tons of asbestos, 50,000 personal computers containing lead and mercury,

300 mainframe computers, hundreds of miles of wire and cable containing polyvinyl chloride and copper, thousands of mercury-containing fluorescent lights, unknown tons of plastics, which would produce dioxins and furans when burned, thousands of chairs and other office furniture containing polybrominated biphenyls, several storage tanks containing petroleum products, and 130,000 gallons of transformer oil.[3] The combustion of this colossal mass of material at the extreme temperatures and force generated by the impact, fires, and subsequent collapse made the situation at Ground Zero even more unprecedented. Members of the NIEHS consortium collected dust samples from the area in the days after the attacks. Within three days of the event, air sampling sites were set up within close proximity to Ground Zero for daily particulate matter (PM) sampling, and bulk samples of settled debris were obtained from several indoor and outdoor sites for subsequent analysis.[4] An air sample provided from an ongoing sampling study within Manhattan was donated as well.[4] These samples provided some of the most comprehensive information on the characteristics that have become widely known, namely that the dust had a characteristic alkaline pH, was mainly composed of pulverized building and construction materials, with some contamination by agents such as lead, asbestos, glass fibers, and **polycyclic aromatic hydrocarbons(PAH)**.[4] Despite the success the investigators had in collecting samples and data on the environmental impact of the event, they encountered several delays and limitations in what they could achieve in the postdisaster environment. There were difficulties in accessing the site, damage to the local infrastructure (electricity), inadequate numbers of sampling devices and trained personnel, and devices that were overwhelmed by excess particulates in the presence of the initial plume.[5]

Despite limitations, much information has been derived from the NIEHS consortium studies. These studies revealed that more than 90% of the particles in the bulk samples tested were >10 microns in diameter, and many were fibers with widths <5 microns and >10 microns.[6,7] While these large particles are generally trapped and cleared by the upper respiratory tract, the massive amount of material had the potential to overcome normal respiratory protective mechanisms, and a study from the consortium demonstrated that these large fibers lodged in human lungs.[8] One area of particular concern was the small particulates of the dust (those particles smaller than 2.5 microns, $PM_{2.5}$), which have the ability to travel to the sensitive distal airways of the lung and evade mucociliary and cough mechanisms of clearance. Although $PM_{2.5}$ represented a small percentage of the particulate mass (10%), the quantity of particulate matter released was so massive that $PM_{2.5}$ levels in the air at the GZ perimeter were very high, typically above the EPA level of concern of $40ug/m^3$, with occasional

increases to 100–400 ug/m^3, according to monitors available after September 21.[9] Characterization of the $PM_{2.5}$ revealed an alkaline pH similar to that of unfractionated dust, with subtle differences in the other substances analyzed (sulfate, PAH).[10] It has been well understood that high levels of non–WTC $PM_{2.5}$ are associated with adverse cardiovascular and respiratory health effects. As a result, there was concern that the WTC dust would represent a particular health risk. Using samples provided by the NIEHS consortium, the investigators at the EPA demonstrated a biologic effect of WTC $PM_{2.5}$ in a mouse model. They showed that airway hyperresponsiveness (AHR) could be induced with exposure,[11] providing proof of concept to the human studies that were being reported at the time.

Members of the NIEHS consortium and the EPA analyzed the PAH content of the dust. As combustion of different types of fuel produce different types of PAH, the types present in the materials collected could be traced back to the airplanes used in the attacks. Dust collected in the days after the event by the NIEHS consortium was compared to those collected several weeks later and were found to have similar types of PAH, indicating that the fires that remained burning at the site were an ongoing source of toxic products of incomplete combustion of jet fuel.[4] Surface dust that had accumulated in indoor areas was also examined and showed a profile of PAH types similar to that collected outdoors in the initial days after the attacks, suggesting a greater likelihood that this dust was a result of the attacks rather than dust that had been present before the attacks took place.[12] It was estimated that 100–1,000 tons of PAH had settled over a localized area. Variations in the levels of individual PAH were identified in indoor bulk samples; these differences were thought to have resulted from the wide variety of unburned and partially burned hydrocarbons from the materials in the collapsed buildings as well as differences in penetration of the outdoor dusts.[13,14]

These findings were a counterpoint to those of the EPA, which had collected samples from the air filters. Analysis of these samples showed that although concentrations of mutagenic and carcinogenic PAH were among the highest reported for outdoor sources on the first days, they rapidly diminished over the subsequent 100 days, after which diesel sources predominated.[15] The EPA concluded that the transient elevation in PAH posed a very small cancer risk among non-occupationally exposed residents of New York City. The human data to support this assertion has yet to be collected. There was little to no communication among the interested public health parties in regard to sampling, analyses (although these took time), publication, or dissemination of results to the public.

Role of the Medical Community in Identifying Adverse Health Effects in Diverse Populations

The Fire Department of New York

Within minutes of the terrorist attacks on the WTC, the Fire Department of New York City (FDNY) operated a continuous rescue and recovery effort at the WTC site involving approximately 11,000 firefighters until May 2002. During the collapse, 343 FDNY rescue workers died and, during the next 24 hours, an additional 240 FDNY rescue workers sought emergency medical treatment, mostly for eye and respiratory tract irritation. Three FDNY rescue workers required hospitalization for life-threatening inhalational injuries.[16] The FDNY had a well-established medical program for routine monitoring and treatment of its members. FDNY members were required to undergo and pass yearly medical evaluations that included lung function testing. The medical officers of the FDNY Bureau of Health Services responded to the rescue and recovery effort at the WTC site by providing rapid emergency medical services. These physicians, many of whom were caught in the initial dust cloud themselves, were the first to report on adverse health effects related to WTC dust and fume exposure in September 2002.

Studies of the firefighter population provide unique insights into the potential adverse health effects of WTC dust and fume exposure for several reasons. First, the firefighters generally had intense exposure to WTC dust and fumes, with short-term intense exposure on the day of the attack and many with sustained daily exposure on the burning pile of rubble over the subsequent months. Second, case ascertainment is complete because all FDNY rescue workers must report to FDNY Bureau of Health Services for regular evaluations if they present to hospitals or treatment centers while on duty, require on- or off-duty medical leave, file workers' compensation, or require retirement disability. Furthermore, firefighters are overall a healthier group than the general population because of the extensive medical screening they undergo to determine employment eligibility. Finally, the firefighter population is the only one reported on to date for which pre–9/11 clinical and pulmonary function data are consistently available.

Within weeks of the terrorist attacks, the Centers for Disease Control and Prevention (CDC) awarded $4.8 million to the FDNY to screen its members for health problems as a result of their early and intense exposure to hazardous conditions at Ground Zero. In the same year, the federal government, in recognition of the high casualties experienced by FDNY and the impact of

the WTC disaster on nearly every member of the department, provided $132 million for treatment and mental health evaluation for FDNY members and to provide crisis counseling in New York City and ten surrounding counties for more than two years after the disaster. These funds were distributed through Project Liberty, which was created by the New York State Office of Mental Health with support from the Federal Emergency Management Agency with a Crisis Counseling Regular Services Grant. The rapid federal response was in response to the New York congressional delegation funding requests, especially because of a special personal interest by Sen. Hillary Rodham Clinton (D-NY).

The work of the medical community of the FDNY allowed the first identification of adverse respiratory and other health effects in those that responded to the WTC crisis.[17] Prezant and colleagues described "World Trade Center cough" (**WTC cough**), defined as cough serious enough to require medical leave for four weeks, and bronchial hyper-responsiveness in FDNY firefighters.[18] Within 24 hours after exposure, all 332 firefighters with WTC cough reported a cough productive of black to grayish sputum infiltrated with "pebbles or particles." In the first six months after 9/11, WTC cough occurred in 128 of 1,636 firefighters with high-level exposure (8%), 187 of 6,958 FDNY with moderate level of exposure (3%), and 17 of 1,320 with low level of exposure (1%). Ninety-five percent had symptoms of dyspnea, 87% had gastro-esophageal reflux symptoms, and 54% had nasal congestion. Bronchial hyper-responsiveness was common in firefighters with WTC cough and in those with high- or intermediate-level exposure. The use of respiratory protection was not associated with a significantly decreased risk of lower airway symptoms, decreased pulmonary function, or airway hyper-reactivity, probably because of the hypervigilant rescue efforts during the first two weeks after the collapse of the towers, with only intermittent use of respirators.

Prezant and colleagues showed that these firefighters were not only symptomatic but that their symptoms were associated with a significant decline in lung function. Mean lung function remained within normal limits; however, forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) showed a drop of at least 0.5 liters in 58% and 54% of firefighters respectively before and after 9/11.[18] Of the seventy-eight firefighters with normal findings on plain chest radiography, high resolution inspiratory and expiratory CT scans were obtained, and air trapping was seen in more than 50% and bronchial wall thickening in 30% of the firefighters. Over the six-month follow-up period, practically all of the firefighters with upper airway symptoms were medically cleared to return to work; only 34% of those with predominantly lower respiratory tract symptoms were allowed to return to duty.[18]

Studies of the firefighters documented the presence of WTC particles and an inflammatory response in the lungs immediately after exposure as well as persistence of these particles and inflammation years after the event. Analysis of bronchoalveolar lavage fluid from a firefighter who worked on the WTC pile on September 24, 2001, and presented with respiratory failure as a result of acute eosinophilic pneumonia revealed fly ash, degraded glass fibers, chrysotile, amosite, silicates, chromium, and asbestos within an inflammatory milieu.[8] Subsequently, sputum obtained from thirty-eight highly WTC exposed FDNY firefighters two years after the event demonstrated ongoing inflammation (increased neutrophils, eosinophils, and matrix metalloproteinase levels) in the presence of particles with a size distribution and composition that was different from unexposed controls and consistent with WTC exposure.[19]

In an effort to elucidate further the relationship between WTC exposure intensity and respiratory symptoms, the FDNY Bureau of Health Services collaborated with the National Institute for Occupational Safety and Health to evaluate symptoms, lung function, and use of personal protective equipment in firefighters.[20] In this study utilizing a stratified random sample of 362 firefighters, firefighters were categorized as high exposure if they were present the morning of the collapse, intermediate exposure if they arrived in the afternoon of the day of the collapse or the next day, or low exposure if they arrived 48 hours after the collapse. The firefighters reported that 19% did not wear respirators during the first two weeks, 50% only rarely, and approximately 70% wore a half-face respirator or disposable mask by the end of the second week. In early October 2001, respiratory symptoms (cough, shortness of breath, wheeze, chest pain) were reported by almost 80% in high- and intermediate-exposure groups, by 46% in low-exposure, and by 9% among unexposed. When compared to lung function performed in the previous year, spirometry performed immediately after WTC exposure showed mean declines of 268 mL and 264 mL for FVC and FEV_1, respectively. Both declined significantly in the high- and intermediate-exposure groups with a striking dose–response, and respiratory symptoms were significantly correlated with lung function decline.

Subsequent studies of FDNY approached the question of persistence of symptoms, whether those who developed new symptoms had a delayed or more chronic asthma-like picture, and whether the symptoms were severe enough to cause disability. In a representative sample of 179 rescue worker firefighters, bronchial hyper-reactivity at one, three, or six months was associated with exposure intensity and airflow obstruction.[21] High-exposure FDNY were nearly 7 times more likely to have bronchial hyper-reactivity than those who had intermediate exposure, and initial hyper-reactivity predicted persistent hyper-reactivity at six months. Among 12,079 FDNY followed prospectively,

WTC–dust exposed FDNY rescue workers experienced a significant decline in adjusted average FEV_1 during the year after the attacks (372 ml) equivalent to twelve years of aging-related decline in lung function.[22] Again, a clear exposure intensity–response gradient was seen, with the most highly exposed individuals faring the worst. The FDNY studies went on to describe a higher incidence of sarcoid-like granulomatous pulmonary disease in FDNY rescue workers[23] as well as significant mental health effects. The FDNY established a lung function referral and treatment program for its members.

The WTC Workers Medical Screening Program

In addition to the 11,000 FDNY workers involved in rescue and recovery, an estimated 40,000 non–FDNY workers were involved in the cleanup of Ground Zero and the Staten Island landfill during the days, weeks, and months after September 11, 2001. These workers included a variety of first responders: police, construction workers, ironworkers, laborers, and public sector workers.[24,25]

The Mount Sinai Irving J. Selikoff Center for Occupational and Environmental Medicine, a university-based, New York State Department of Health (NYS DOH)–supported occupational health center, began evaluating these workers within weeks of the event. Officials from the National Institute for Occupational Safety and Health began regular conference calls to enhance communication among the health care workers providing care for the responders. Numerous labor organizations concerned about the health of their constituents and physicians at Mount Sinai Medical Center began advocating among nationally elected officials and representatives about the need for a monitoring program. These efforts resulted in the award of federal funding in April 2002 for the establishment of a medical monitoring program for WTC rescue and recovery workers. The WTC Worker and Volunteer Medical Screening Program was established at Mount Sinai, with additional clinic sites at State University of New York-Stony Brook, Queens College, UMDNJ-RWJ New Jersey Medical School, and New York University-Bellevue Hospital, all of whom were members of a pre-existing infrastructure of the New York State Occupational Health Clinic Network.

The design of this program began in April 2002 and implementation started three months later.[26] Numerous challenges were faced in the design of the program, including the limited data on exposures and potential health consequences, the absence of a systematic roster of responders, and the potential diverse needs of the responders.[27] Although some of the clinical screening evaluations were based on asbestos screening, the clinical screening examination was expanded to include an exposure questionnaire, physical and mental health

questionnaires, a standardized physical examination, spirometry, complete blood count, chemistries, and chest radiograph.[26] After an initial baseline evaluation, individuals were given appropriate referrals for further care if needed and were educated about potential hazards at the WTC and other work sites.

These initial funds were intended for medical and mental health screening of individuals involved in rescue, recovery, and debris removal but not for treatment of these individuals. Moreover, funds were never available on a long-term basis but rather were provided as congressional appropriations, thus requiring continued advocacy efforts and precluding long-term planning. Continuing funds for the program and support for a longitudinal monitoring program were provided in 2003 when Sen. Hillary Clinton and Representatives Caroline Maloney (D), Jerrold Nadler (D), and Vito Fossella (R) promoted the first congressional appropriations of $90 million for the FDNY and workers' responder program, now called the WTC Worker and Volunteer Screening and Monitoring Program. Private philanthropy supported a program for treatment of some of the responders; this program was expanded in 2005 with the provision of increased funding from the American Red Cross Liberty Disaster Relief fund. In 2006, NIOSH funds were increased to include treatment, and the program was renamed the WTC Worker and Volunteer Monitoring and Treatment Program.

Of the first 9,442 responders examined in the WTC Worker and Volunteer Monitoring Program between 2002 and 2004, 69% reported new or worsened respiratory symptoms while performing WTC work, and these persisted until the time of examination in 59% of them.[25] Sixty percent of these workers reported having been in the initial dust cloud on 9/11. Upper respiratory symptoms, cough, dyspnea, chest tightness, and wheeze were the most common symptoms. There was a significant association between the presence of a low FVC and the time of arrival at the site, with a higher prevalence of abnormality in those who arrived earlier. In a study of longitudinal lung function consisting of baseline and follow-up spirometry in 3,160 workers, 20% had a low FVC on the first examination and 16% on the second.[28] Eight percent had obstruction at both examinations. The decline in FEV_1 was 13 mL/year, but 131 individuals lost greater than 300 mL of FVC annually. No special associations were noted for this rapid decline group, and respiratory symptoms at first examination were not predictive of lung function decline. Radiographic imaging using CT scans in a subgroup of workers revealed air trapping, consistent with that described in the FDNY study.[29] Data from this worker cohort also provided descriptions of gastroesophageal reflux symptoms[30] as well as information on social and mental health issues. Of more than 10,000 workers surveyed, 11% had symptoms consistent with

post-traumatic stress disorder (PTSD), a rate higher than that seen in the general population.[31] Many had concurrent depression and anxiety.

In summary, the collaboration between labor forces and an existing occupational program allowed for the rapid implementation of a comprehensive medical program as well as the ability to advocate at the federal level for funding for this program. The expansion from a screening and monitoring program to a program offering medical treatment required continued advocacy but became an invaluable resource for those without adequate health insurance and allowed for the development of expertise among medical practitioners.

Local Residents, Workers, and Children

Residents

At the community level, no organized group represented residents at the time of the 9/11 attack. After 9/11 there were some minor efforts to combat community health risks. For example, EPA counseled that tenants use "appropriate" equipment but failed to specify respirators.[32] Additionally, the New York City Department of Health and Mental Hygiene (NYCDOHMH) distributed leaflets recommending cleaning techniques, such as shampooing carpets, using wet rags and mops and HEPA vacuum cleaners.[33] Community physicians were less well equipped to deal with exposure complications than were occupational physicians. This was because community physicians had fewer sources for information and no clear recommendations for their patients. Those who listened to the results of monitoring provided by the EPA and the NYCDOHMH tried to alleviate the fears of their patients. Others recommended that patients move, if only temporarily.

These problems were especially acute given the number of people affected by the disaster. Indeed, estimates suggest that approximately 300,000 nonresponders were at risk for exposure from the WTC disaster.[34] This population included the daily workforce (estimated at greater than 250,000), grade school students (8,000), students in local colleges (45,000), and the more than 60,000 residents living south of Canal Street.[34,35] The local residential, working, and school population had potential for multiple exposures to WTC dust, fumes, and gasses. Some were caught in the initial debris as the buildings were hit. Many were caught in the initial dust clouds as the multiple buildings collapsed, and some wandered for hours in the debris immediately after the collapse. Those who lived on the west side of Manhattan were evacuated for days to months after the event: 19,000 families were displaced and forced to find

temporary lodging, some for more than one year.[36] These individuals were especially at risk because there was no systematic way in which affected apartments were cleaned. Some hired cleanup agencies, most of which were staffed with unskilled workers; others cleaned on their own. Cleaning of ventilation systems was inconsistent. Although funding was available for replacement of furniture and carpeting for some, the distribution of this funding was haphazard, and recommendations regarding under what circumstances furniture ought to be replaced were not available.

Workers

Individuals who worked in the area were also put at risk. Although businesses in Lower Manhattan closed immediately after the event, nearly all offices reopened one week later. Workers returned with patriotic enthusiasm to offices that had undergone varied degrees of cleaning. Again, in the absence of formal recommendations, some were cleaned with vigilance, and others were cleaned partially, with ventilation systems ignored.

Schools, too, experienced problems that led to exposure. On 9/11, the local schools dealt with the emergency in a variety of ways. Some opened their doors and told the children to run. Others shut the children in the building, only letting them out after the towers had collapsed. All closed for weeks to months. The cleanup activities of these schools were varied and depended on advocacy from parent-led organizations. Continued fumes and dust generated by the ongoing fires and the re-suspension of dust from the WTC site required continued cleaning activities, none of which were formally recommended by governmental agencies. Anecdotes of respiratory complaints emerged within days.

In response to these various hazards to the community, members of the New York State Department of Health and physicians at New York University began a collaboration to design a study to investigate respiratory health effects in local residents. Funding for this project was provided by the Centers for Disease Control. Together they met with community members of local tenants' organizations, community boards, newly formed environmental groups, and local advocacy groups. The WTC Residents Respiratory Health Study was designed, implemented, and completed within the first year and a half after 9/11. This study included sampling of residents within a 1-mile radius of Ground Zero (exposed population) as well as those in a control group. The exposed population was oversampled, because at the time the study was the only survey of residents, and the plan was to develop this group as a longitudinal cohort. Questionnaires in English, Spanish, and Chinese were mailed; however, with the dysfunction of postal service due to the disruption of the attack and the concurrent anthrax

scare, questionnaires were subsequently hand-delivered, building by building, door to door.

This study resulted in the first documentation of the presence of health effects in a local population of residents exposed to deconstructed, pulverized, and incinerated buildings.[37] Among the more than 2,800 residents who answered the questionnaire, there was a greater than threefold increase in the presence of new-onset persistent respiratory symptoms compared to the control population. More than 6 times as many exposed individuals had new-onset wheezing compared to the control population. Furthermore, higher rates of new-onset upper respiratory symptoms were associated with unplanned medical visits and increased use of rescue inhaler medications.[38] Adverse home conditions, such as the presence of physical damage, dust, and odors, were related to new-onset respiratory symptoms, with the greatest risk observed in individuals who reported an increased duration or frequency of dust or odors in their homes, suggesting a dose–response.[39] Although the study was completed and the manuscript written within the first two years of the event, these studies were delayed in publication as they wound their way through governmental and peer review. The results were borne out in other studies, which suggested increased asthma rates in the community and increased asthma-related clinic visits among asthmatic children living near the WTC site after 9/11.[40,41]

Children

As in many toxic environmental exposures, developing fetuses and young children are generally more susceptible to adverse effects due to the vulnerability of developing organ systems, the neurologic system in particular. Because Lower Manhattan had become an increasingly popular neighborhood for young families, the number of children and pregnant women in the area was substantial. In addition, there were many pregnant women in the workforce. The NIEHS Environmental Center at Mount Sinai Hospital examined a cohort of 187 pregnant women with exposures via residence or occupation stratified by an exposure index that took into account distance from the site and direction of debris dispersal based on PM measurements in the area. Although no statistically significant differences in the formation of DNA adducts related to PAH exposure, PCBs, or dioxins were detected, women who had samples collected shortly after the event had elevated PAH-related DNA adducts compared to those who submitted samples several months after the event. In addition, reduced intrauterine growth was reported.[42,43]

The Columbia Center for Children's Environmental Health at Columbia University's Mailman School of Public Health embarked on several studies to

determine phenotypic effects the exposure may have had on birth and developmental outcomes. Initial review of birth records from three downtown Manhattan hospitals showed significantly lower birth weight and length among babies born at term to WTC-exposed women than to unexposed women. Women who were in their first trimester of pregnancy at the time of the attacks were found to have a small but significantly shorter period of gestation (−3.6 days) and newborns with smaller head circumference when compared to women exposed at later stages of pregnancy.[44] No difference in mercury levels in cord blood could be found between WTC-exposed and control subjects. There was an increase in DNA adducts, suggesting a cancer-related risk, although the adduct level was less than amounts found in cities with higher pollution levels in Poland and China.[45,46] The difference in DNA adducts present in the WTC area compared to other areas of NYC correlated with smaller birth size as well as with standardized measurements of child development.[45,47] Long-term developmental consequences remain an ongoing area of concern and research. Unfortunately, no funding has been available to continue longitudinal study of the first children studied at Mount Sinai Hospital. The WTC EHC screening and treatment program has expanded to include children who were residents or students in the area during the attack. The DOHMH has provided medical guidelines about the detection or treatment of WTC-related illness in children.

WTC Environmental Health Center

Local residents and workers with WTC-related illness sought care in a variety of locations. Because of the high profile generated from the **WTC Residents Respiratory Study** and Bellevue Hospital's ability, as a local public hospital, to treat uninsured patients, some sought care at the Bellevue Hospital Asthma Clinic. Failing to acquire a governmental program, the Beyond Ground Zero (BGZ) Network approached the administration at Bellevue Hospital and, with the physicians running the asthma program, began a pilot program to treat residents with presumed WTC-related illness. This program expanded in 2005, when it received three years of funding (approximately $2 million) from the American Red Cross Liberty Disaster Relief fund to develop the first treatment program for local residents and workers with WTC exposure and symptoms. A community advisory committee was organized to help define the populations most in need, to provide outreach for the program, and to provide guidance around services that were needed. The committee expanded to include a wide range of affected persons, including residents, local workers, small business owners, students,

and labor representatives. Advocacy from these community organizations resulted in an additional five years of funding provided by the City of New York for an expanded and ongoing treatment program for adults and initiation of a pediatric program. In 2008, after advocacy from governmental representatives, including then-senators Clinton and Schumer and congressional representatives Maloney, Nadler, and Fossella, as well as continued pressure from the City of New York and community groups, money was provided to the Centers for Disease Control and a three-year grant was awarded by NIOSH for a "nonresponder" program to provide expanded medical and mental health treatment services for community members with presumed WTC-related illness.

The World Trade Center Environmental Health Center (WTC EHC) was developed as a comprehensive medical and mental health treatment program based on requests from community representatives. Although recruitment for the program continues, more than 5,000 individuals have enrolled for treatment in the program. These members have predominantly respiratory complaints of dyspnea, cough, and wheeze that began after 9/11 and persist nearly eight years after the event.[48] Lung function abnormalities have been detected in some, while others have hyper-reactive airways. Many have concurrent gastrointestinal symptoms, and there is a very high rate of PTSD, depression, and anxiety. The need for the program has been challenged, and the question has been raised repeatedly about causality and attribution. Due to the absence of pre-existing medical data in this community, and the absence of a program providing screening and evaluation in the immediate aftermath of the event, causality can only be presumed based on standard criteria.[48]

Although the medical consequences of the attack were not clearly evident until several weeks after the event, the potential for significant mental health issues was recognized and acted upon immediately. Many of the large corporations in the financial district hired on-site counselors to help their employees cope with the trauma and fear that resulted from the attacks, and multiple governmental and nongovernmental relief agencies provided mental health services on a walk-in basis (Project Liberty). Within weeks, a formal survey of a broad area of the city was undertaken by the New York Academy of Medicine in conjunction with New York University, Columbia University, and the National Crime Victims' Research and Treatment Center of the Medical University of South Carolina. Data from 1,008 respondents were obtained, and the prevalence of symptoms consistent with PTSD or depression were 7.5% and 9.7% respectively, which is approximately twice the rate given in historical estimates. Extrapolation of these estimates to the

geographic range sampled (area of Manhattan below 110th Street) suggests that there were 67,000 individuals with PTSD symptoms and 87,000 with depression during the month the survey was conducted between mid-October to November 2001.[49] A follow-up survey performed by a different group of investigators three to six months after the attacks indicated that while the number of those with symptoms had decreased, a relatively small percentage (11.9%) had sought psychiatric services or were taking medications for anxiety, depression, or psychotic conditions, despite the increased treatment capacity that had been put in place.[50]

The WTC Health Registry

In 2003, the New York City Department of Health and Mental Hygiene in conjunction with federal, state, and private agencies launched a program to collect data on the physical and mental health issues in the exposed populations. This was named the **WTC Health Registry (WTCHR)** (www.wtcregistry.org). This $20 million joint research program developed by the federal Agency for Toxic Substance and Disease registry and the New York City DOHMH had a goal of monitoring of the health of people directly exposed. It would also create and propose guidelines for future disasters. Initially met with hostility by local community members and labor because of their lack of inclusion in the development of the project, an advisory panel was subsequently developed that included these advocacy groups. To date, the WTCHR is the largest effort in U.S. history to study health effects of a disaster and has enrolled more than 71,000 exposed people. The goal is to monitor the cohort for at least a twenty-year period; however the funding for the program depends on federal agencies.

The WTCHR began voluntary enrollment in 2003–2004. People who lived, worked, or were involved in rescue and recovery efforts were invited to complete a confidential baseline health survey, which included their location on 9/11, their experience on that day and in the aftermath, and any symptoms they developed after their exposure. In 2006, the first adult survey in the registry was completed; the data revealed that 67% of survivors of collapsed or damaged buildings reported new or worsening respiratory symptoms, including cough, shortness of breath, wheezing, or sinus irritation. Nearly 3% (n = 1,967) reported a new asthma diagnosis after 9/11, suggesting a 2–3 times higher rate than would be expected in the general population.[34] Mental health outcomes were monitored; 16% of adult enrollees screened positive for current PTSD, with 8% having serious

psychological distress.[34,51] Health findings among children in the registry ($n = 3184$) demonstrated that WTC exposure increased the likelihood of a new asthma diagnosis, with twice the likelihood of the diagnosis if the children were caught in the dust cloud.[52] In addition, 6% of children under 5 years of age had a reported diagnosis of asthma after 9/11, a rate twice that reported in the Northeast for the same age group. The data demonstrate that the registry enrollees were heavily exposed to physical and psychological risks and that these exposures correlate with symptoms.[51] There were limitations of the WTC Registry, including the delay in implementation of the survey allowing for recall bias, the lack of a control population, making it difficult to calculate the expected background incidence of diseases, and the possibility of selection bias. These limitations notwithstanding, the WTCHR is an essential resource for understanding the long-term health effects of the 9/11 attacks among adults and children.

Several subgroups of the registry population, including rescue and recovery workers, residents, and local workers, have submitted to in-depth evaluations to determine health effects in specific populations. So far, although methodologically different from the studies at the clinical centers, the results of the registry studies have been consistent with the findings in the FDNY and labor studies. Review of registry data on 25,748 rescue, recovery, and cleanup workers revealed a risk of asthma twelvefold higher than the expected background three-year risk in the general population (3.6% versus 0.3%).[53] Significant risk factors for worse health outcomes were earlier arrival at the site, longer duration of work, exposure to the dust cloud, and working on the pile at the WTC site.

Further in-depth studies have looked at mental health issues, particularly in rescue and recovery workers and volunteers. In an analysis of 28,962 WTCHR rescue and recovery workers interviewed two to three years after the disaster, the prevalence of PTSD was 12.4% and ranged from 6.2% for police officers and 21.2% for unaffiliated volunteers.[54] The highest rate of PTSD was documented in construction workers and engineers, volunteers, and sanitation workers, suggesting that performing tasks not relevant to one's occupation poses a distinct risk, a finding relevant for future disasters. When Lower Manhattan residents ($n = 11,039$) who resided within 1 mile of the WTC site were evaluated for psychological stress two to three years after 9/11, an estimated 12.6% rate of probable PTSD was found and was associated with older age, female gender, Hispanic ethnicity, and low socioeconomic status.[55] This rate was estimated to be 3 times higher than would be expected had the WTC attack not occurred and has raised awareness that psychological symptoms may persist eight years after the event.

Lessons Learned

The events of 9/11 and their aftermath were tragic and resulted in the worst environmental disaster in the history of New York City. The response of the medical community highlights both the strengths of the community and its weaknesses, and some lessons have been reviewed elsewhere.[27,56] In an environmental catastrophe, who is responsible for the medical response? What is the chain of command? Scores of medical personnel ran to the WTC site and offered their help during the immediate crisis, and all hospitals were on emergency standby during the first few days; however, there was no coordination for the medical response to subsequent environmental issues. The lack of expertise of the local governmental agencies in toxicologic or environmental health monitoring became apparent early on and could have been remedied by collaborations with experts in the field; these collaborations were slow to develop, although they have strengthened in the subsequent years. Furthermore, when decisions about public health were made by governmental entities concerned with economic and security issues as well, the inherent conflict of interest may put communities at risk. Thus, rapid independent input from private as well as academic medical and scientific communities is needed in the setting of environmental disasters.

These same medical and academic communities need to learn to work with one another for the public good. There is a conflict between the need for rapid information and the snail's pace at which the medical community develops and presents its data. Data cannot be presented to the press, the fastest route of communication, until it has been published in a peer-reviewed journal. But the peer review and publication process can take months, if not years, and depends on reviewers and editors who may have lost interest in the subject. In addition, the reality of medical communities is that they function as independent and competitive groups, each vying for funding for its own institution. Collaboration is often limited because of this competition. The academic and medical response to the WTC crisis used some pre-existing structures to overcome some of these limitations. The presence of a network of NIEHS centers provided a forum for communication and the ability to share resources that led to some of the most comprehensive toxicologic analyses. The presence of pre-existing occupational health centers allowed for the development of a network of programs that comprised the WTC Workers Monitoring and Treatment Program. The absence of any such network in place for the nonresponder community highlights this need.

Finally, there is a difference between toxicologic studies and health responses. Toxicologic studies monitor levels of chemicals, but the human response to these chemicals requires human studies. Some of the chemical compounds in the WTC dust might have been expected to have been present; others, because of the extreme pressure and heat, were difficult to identify and remain unknown. The true levels of exposure will never be known. Assumptions derived from studies of healthy humans may not hold true for a diverse population with individuals who may have greater susceptibility for adverse health effects (children, the elderly, and individuals with comorbid conditions). Thus, all populations, not only the most highly exposed but also those with a potentially lower exposure but greater susceptibility, need to be monitored. In addition, if there is no knowledge about the response to a compound or mixture of compounds, or if the level of exposure is not measurable, as in those persons exposed to the dust cloud, an assumption of the absence of an adverse health effect should only be made after study results are available. The finding of adverse WTC health effects in every population studied suggests the need for greater vigilance in future disasters. The criticism of all studies on the basis of recall bias or lack of control populations should be a reminder that these studies ought to have been implemented more rapidly. Two years later is too late.

Summary

Perhaps the most important lesson to be learned from the medical response to the WTC events is the importance of partnership among the affected populations and academic and government agencies. The medical response for the FDNY had an advantage in that it was already in place on 9/11 as part of an ongoing medical program. In contrast, it was the organized efforts of politically skilled labor organizations that established a health program for their constituencies. And it was the loud, unrelenting, often angry efforts of diverse grass-roots community organizations that eventually won a health program for their disparate communities. Rather than disregard lay anecdotes and stories, physicians and scientists should consider these reports as the most sensitive and earliest indication of a need for a medical and scientific response. The WTC environmental disaster of respiratory exposures to alkaline dust with adsorbed PAH, metals, and other compounds is now being repeated in the aftermath of the BP Gulf oil spill, where workers are exposed to high levels of crude oil and its volatiles and dispersants, cleanup workers are exposed to oil and tar balls that wash up on beaches, and community

residents are exposed to oil and volatile hydrocarbons as well as the mental stress associated with lost income.

Key Terms

National Institute for Occupational Safety and Health (NIOSH)

National Institutes of Environmental Health Science (NIEHS)

Polycyclic aromatic hydrocarbons (PAH)

The World Trade Center Environmental Health Center (WTC EHC)

WTC cough

WTC Health Registry (WTCHR)

WTC Residents Respiratory Study

Discussion Questions

1. What was the government's immediate response to the health risks of the WTC disaster?
2. What information did the government disseminate about the health risks of the disaster?
3. How was the cleanup of WTC materials organized?
4. What were the results of the exposure risk research surrounding those affected?
5. What are some of the long-term health effects of exposure to WTC disaster materials?

ENVIRONMENTAL POLICY AND PUBLIC HEALTH

Air Pollution, Global Climate Change, and Wilderness

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