Cancer Investigation, 24:294–301, 2006
ISSN: 0735-7907 print / 1532-4192 online

DOI: 10.1080/07357900600633965

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Taylor & Francis Group

ENVIRONMENTAL CARCINOGENESIS

Health Consequences of the September 11 World Trade Center Attacks: A Review

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ABSTRACT

In the aftermath of the September 11 World Trade Center (WTC) attack, a large number of people sustained potential exposures to smoke, dust, particulate matter, and a variety of toxins, including asbestos, pulverized concrete, glass fibers, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated furans and dioxins. Additionally, many had exposure to psychological traumatogens. The most common effects seen to date are respiratory and mental health consequences. The long-term consequences of exposures are not yet known, and there remains concern about the potential for late-emerging diseases such as cancers. This article reviews WTC-related health effects, the spectrum of exposures and how they were documented, and discusses future preventive efforts.

INTRODUCTION

The September 11, 2001 attacks on the World Trade Center (WTC) resulted not only in horrific loss of life, but in the creation of an urban environmental disaster that resulted in significant and persistent health consequences. The crash of 2 commercial jetliners with almost 100,000 liters of jet fuel (1) into the 2 towers resulted in explosions and extremely high temperature fires (>982.2°C) that burned both structural elements of the towers as well as their contents. The collapse of the towers resulted in the pulverization of as much as one million tons of building material, including glass, steel, concrete, and sheet rock. The burning and pulverization of the buildings resulted in a large plume of smoke that released gases and particles in Lower Manhattan and additionally created a dust cloud that initially was dispersed in all directions (2). Environmental exposures in the immediate aftermath of the disaster included asbestos, pulverized concrete, glass fibers, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated furans and dioxins (3–5). Additional exposures of concern in the immediate aftermath of the attack include physical hazards (heat, unstable surfaces, ongoing fires, and exposure to psychological traumatogens).

An estimated 250,000–400,000 people sustained WTC-related exposures in New York (6). While those present in lower Manhattan on September 11 are likely to have sustained the greatest exposures to both environmental toxins and psychological traumatogens, hazardous environmental exposures continued over many months, and a substantial number of people sustained longer term, albeit lower level exposures, for many months after the disaster

The WTC-related health effects identified most commonly to date include acute and persistent respiratory illnesses and mental health consequences. The long-term consequences of WTC exposures are as yet unknown, but may include late-emerging diseases, such as cancers and chronic sequelae of current WTC-related illness. Additionally, the potential for synergistic effects of exposures to both multiple environmental contaminants and mental health traumatogens remains of concern. This article will review the literature on WTC-related health effects, the spectrum of exposures and how they were documented, and will discuss future preventive efforts.

Keywords:
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EXPOSURES

There are numerous studies (4, 5, 7–10) that describe environmental conditions and potential toxic hazards in the

post-September 11 Lower Manhattan/WTC area. Exposure assessments show that the destruction of the WTC towers resulted in the release of high levels of airborne contaminants (5). In the first 12 hours after the attacks, the predominant sources of exposures were burning jet fuel and the tower collapses, followed in the next 2 days by exposures due to continued burning of jet fuel and building contents and the re suspension of settled dust. Exposures continuing through December 2001 were due primarily to smoldering fires and dust re-suspension as well as diesel exhaust from heavy equipment. Fires ended by December 2001 and, therefore, subsequent exposures were due only to re suspension of WTC dust and heavy equipment emissions.

The unprecedented magnitude of the collapse—6 million square feet of masonry, 5 million square feet of painted surfaces, 7 million square feet of flooring, 600,000 square feet of window glass, 200 elevators, and all other items present in a modern office complex (11)—resulted in a massive cloud of dust and smoke that engulfed Lower Manhattan. This dust settled, was resuspended and settled again over several days (11). The Environmental Protection Agency (EPA) estimates that during the first few hours after the collapse, potential dust exposures ranged from 1,000 mcg/m^3 to over 100,000 mcg/m^3 (12).

WTC settled dust consisted primarily (95 percent) of large particulate matter that contained pulverized cement, glass fibers, asbestos, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and polychlorinated furans and dioxins. Unique patterns and highly elevated levels of polychlorinated dioxins and furans were found on exterior window films in Lower Manhattan (13). The pH of most samples of WTC dust exceeded 10, a pH well capable of causing irritation to mucus membranes. Glass fibers from window glass and fiberglass comprised 40 percent of some samples (4, 11). In the larger particulate matter, in addition to glass fibers, gypsum ($CaSO_4$), and calcite ($CaCO_3$)—the main component of limestone—predominated. Within samples of smaller particulate matter, $PM_{2.5}$, the particle size capable of penetrating into the smaller airways and lung parenchyma, calcium and sulfuric oxide compounds predominated, originating from construction materials such as cement, concrete aggregate, ceiling tiles, and wallboards (5). Gypsum and calcite are known upper airway irritants and calcium carbonate dust causes coughing, sneezing and nasal irritation (14).

To assess the size distribution of settled dust, Lioy (4, 5) sieved and aerodynamically separated samples. More than 95 percent of the dust was larger than 10 microns in size and thus too large to penetrate into the human respiratory tract (15). However, the sheer volume of dust in the air meant that even if 5 percent of the dust was smaller than 10 microns, it could pose a substantial health risk to individuals in Lower Manhattan, particularly among those at the WTC site in the hours and days immediately following the collapse. Additionally, while the pH of a particle tended to decrease with decreasing particle size, deposition of larger, high pH particles in the upper respiratory tract may have resulted in persistent upper airway disorder. Individuals who were present at the site for several months were also at risk for lower-level but more sustained exposure.

In addition to massive dust exposure, there was also exposure to products of combustion from fires that persisted from September 11, 2001 to December 20, 2001. Assessment of airborne $PM_{2.5}$ samples collected on or after September 14, 2001 revealed that levels of $PM_{2.5}$ were very highly elevated above urban background levels. Measurements of dioxin-like compounds and volatile organic compounds (from combustion and volatilization of fuels), polychlorinated biphenyls (from dielectric fluid in transformers and capacitors), and metals, including lead, chromium and nickel compounds, were elevated at the World Trade Center site (2, 4, 5). While no PAH measurements were performed until September 23, 2001, models predicted that exposures three days after the collapse of the towers ranged from 1.3 to 15 ng/m^3, some of the highest values ever reported from outdoor sources.

Payne et al. (16) performed an in vitro study on the effect of particulate matter from the WTC on markers of oxidative stress (gamma-glutamyl-transferase, or GGT) and cytokine release from human lung (alveolar macrophages and epithelial) cells. Increased levels of IL-8 and IL-6 were noted, as well as in increase in levels of GGT expression. The authors found that cultured human cells exposed to dust from the WTC, particularly in the $PM_{2.5}$ range, exhibited increased oxidative stress and cytokine release. These results are consistent with levels of cytokines found in induced sputum of individuals with chronic cough (17), and may explain some of the respiratory symptoms described in individuals with exposure to dust from the WTC collapse.

Gavett et al. (8) performed experiments on mice, exposing them to dust collected on September 12 and 13, 2001 from sites near the World Trade Center. Mice exposed to high doses of WTC dust developed mild to moderate lung inflammation. However, of greater significance was the finding that those animals exposed to a higher doses of WTC dust (comparable to an equivalent human dose of 425 mcg $PM_{2.5}$/m^3, a level that was likely to have existed at the WTC site) developed hyper responsiveness to methacholine comparable to the degree of hyper responsiveness seen after exposure to "standardized air" PM and greater than that of control mice exposed to fly ash. This finding in mice indicates that the group of mice receiving a high dose of WTC dust was primed to react to triggering agents that can constrict the airway (18).

A mineralogical analysis of bronchoalveolar lavage fluid from a firefighter working at the World Trade Center site who developed acute eosinophilic pneumonia was performed by Rom et al. (19). The fluid contained fly ash, degraded glass, chromium, metal particles, various silicates and large numbers of asbestos fibers (19). In a study of induced sputum collected from New York City firefighters up to 8 months after the WTC disaster, Fireman et al. (20) further characterized the actual WTC exposure and its effect in the lung. The particle size distribution and composition of the sputum was similar to WTC dust samples. Highly exposed NYC firefighters had greater numbers of inflammatory cells in their sputum than unexposed controls or firefighters without WTC exposures. The FDNY firefighters also had higher levels of MMP-9, a marker of inflammation, than non-WTC exposed firefighters. This study also demonstrated that the larger particles, which were highly alkaline were capable of

penetration deeply into the lung and, thus, capable of causing significant damage.

In order to assess exposure to potentially WTC fire-related compounds, blood and urine specimens from firefighters who were working at the WTC site were compared to firefighter controls were not present at the WTC site (21). Samples were collected 3 weeks after September 11 while the WTC fires were still burning. Products of combustion, represented by PAH metabolites, and measured by the urinary metabolite, 1-hydroxypyrene, were higher in exposed firefighters. Levels of urinary antimony, serum heptachlorodibenzodioxin and heptachlorodibenzofuran were also higher, although not all levels were considered to be of clinical concern. Special Operations Command firefighters (i.e. rescue, squad, and marine units), who respond to fires of greater intensity more frequently, and have different job tasks than engine and ladder firefighters, were also more likely to have been present at the collapse of the WTC. For 11 of the 13 chemicals that were statistically significantly elevated compared to firefighter controls, firefighters in Specials Operations Command had higher concentrations. The authors caution, however, that it is unclear whether the differences between Special Operations Command firefighters and other exposed firefighters reflects WTC exposures alone, cumulative exposures occurring from firefighting duties prior to September 11, or a combination of both. Environmental exposures among a subset of pregnant women at or near the WTC site on September 11, 2001 measured in blood and urine showed evidence of intense bystander exposures after the WTC collapse (22).

HEALTH EFFECTS

Acute physical health effects among disaster responders

Musculoskeletal conditions comprised the most common type of acute injury in responders. Among those, strains/sprains, lacerations and abrasions were the most frequent. Despite the unstable nature of the debris pile, fractures accounted for less than one percent of visits to the on site medical care units or emergency departments. Respiratory conditions were the second most common reason rescue and recovery workers sought care, followed by eye-related visits (23). Among 240 FDNY rescue workers who sought emergency room treatment in the first 24 hours after the attack, most were seen for eye irritation, respiratory tract irritation, and exposure; over 90 percent of the firefighters did not have injuries severe enough to warrant hospital admission (24).

Acute physical health effects among workers and residents from the surrounding community

The New York City Department of Health and Mental Hygiene quickly implemented Syndromic Surveillance in hospital emergency departments to identify a large-scale bioterrorist event and other health conditions related to the WTC attack (25). Investigators determined that individuals reporting proximity to the WTC site on September 11 were 61.5 times more likely to visit an emergency department for smoke/dust inhalation compared with those 2 miles or more from the WTC site. Visits related to anxiety, trauma and asthma were all statistically significantly higher for those within a 2-mile radius of the WTC.

In addition to environmental exposures, WTC responders experienced a wide variety of exposures to psychologically traumatic events. These include, but were not limited to being physically present at and witnessing the events as they were happening, being in physical danger during the events, and searching for and recovering human remains and other debris (26). Workers involved in rescue and recovery efforts came from a wide range of occupations and included members of the construction trades, sanitation workers, cleaning and maintenance workers, and other blue collar workers who had never been trained for, nor expected to experience, work in a disaster setting.

Short- and medium-term physical health effects among disaster responders

WTC disaster responders comprise a heterogeneous group that includes both traditional first responders, such as firefighters, and less traditional responders, such as construction workers. Airway inflammation due to WTC dust, demonstrated in in vitro, animal and human sputum studies, was also clinically evident in many WTC responders. Multiple studies of WTC responders from a wide variety of occupational groups show respiratory effects related to WTC exposures. These studies are summarized below.

Prezant et al. (27) found that 90 percent of New York City firefighters working at the site in the first 48 hours after the attack complained of an acute cough, often accompanied by nasal congestion, chest tightness and chest burning and indigestion (24, 27). Prezant was the first to describe "WTC cough," a cough that began and persisted after working at the WTC site, and was severe enough to require at least 4 consecutive weeks of medical leave. Increased bronchial reactivity was found in 31 percent of firefighters who were present at the WTC site on September 11, 2001, as well as 25 percent of all exposed firefighters participating in a randomly selected follow-up study (27). Firefighters with bronchial hyperreactivity were more likely to have persistent respiratory symptoms and require respiratory-related medical leave. Those firefighters present on September 11 were 7.8 times more likely to be hyper reactive at 6 months than firefighters with lower WTC exposures, and in fact, their hyperreactivity appeared to worsen over time. This increased hyperreactivity persisted up to 2 years after September 2001 (28). These firefighters continue to report respiratory symptoms as well as an increase of sinus and gastroesophageal reflux disease symptoms. Pulmonary function declined in firefighters who were present on September 11–13, 2001. The average decline in forced vital capacity (FVC) and forced expiratory volume (FEV_1) among firefighters was 300–500 milliliters compared to pre-September 11 levels, a significant decrement and more than would be expected from normal aging (29). These significant

changes might not have been noticed without the availability of prior pulmonary function testings, since their FVC and FEV_1, while lower, still fell within the "normal range."

Similarly, a study of 240 police officers, of which 86 percent were present at the WTC site on September 11, was conducted approximately 2.5 months after the WTC collapse. Seventy-eight percent of study subjects developed new or worsening respiratory symptoms as a result of their exposures (30). Abnormal spirometry was noted in 28.8 percent of participants, and individuals with the highest intensity exposure were more likely to have abnormal spirometry.

Physical health assessments conducted between July and December 2002 of a heterogeneous group of 1,138 workers and volunteers who performed rescue, recovery and restoration of services in the aftermath of the WTC disaster showed that a majority of these responders experienced new onset or exacerbation of pre-existing lower respiratory symptoms (60 percent), 74 percent had WTC-related upper respiratory symptoms while performing WTC-response activities, 40 percent of the examinees had new onset lower respiratory symptoms that were persistent to the month prior to screening, and 50 percent reported WTC-incident and persistent upper respiratory symptoms. Among the 851 participants (75 percent) who reported persistent WTC-related symptoms, an average of 32 weeks (range: 7–63 weeks) lapsed since either they stopped working at the site or since the close of the site at the end of May 2002, suggesting persistence. Thirty-three percent of participants had abnormal spirometry results. Among the 599 participants who had never smoked, there was a higher prevalence of abnormalities on spirometry (31 percent) compared to 13 percent of the general population sample of employed, adult, White males [NHANES III] (31, 32).

In a cross-sectional study, Skloot et al. (33) found that the majority of ironworkers present at the WTC site from September 11–15 had one or more respiratory symptom 5 months after the WTC collapse. Forced oscillation testing showed that 53 percent of non-asthmatics evaluated had elevated respiratory resistance, indicating evidence of lung function abnormalities.

Short- and medium-term physical health effects among office workers and residents from the surrounding community

The majority of studies looking at WTC-related physical health outcomes among residents or office workers have found patterns of respiratory complaints that are very similar to those seen among responders.

Federal employees working near the WTC site were compared to a similar group of workers in Dallas, Texas. In this cross-sectional study (10) that took place 2–3 months after the collapse of the WTC towers, workers in Lower Manhattan had significantly higher rates of constitutional symptoms such as shortness of breath, chest tightness and eye irritation, compared with the Dallas workers.

Studies of high school and college staff present in the region of the WTC at the time of the collapse show an increased prevalence of eye, nose, and throat irritation, cough, nausea, and shortness of breath compared to similar educational staff located 5 miles from the WTC site. The majority of the survey participants were present during the collapse of the towers and ensuing fires, and were exposed to smoke, respirable airborne particles, fire dust, and fire combustion products (34).

A study of women who were pregnant on September 11, 2001 and were in Lower Manhattan either on September 11 or within the succeeding 3 weeks found an apparent association between maternal exposure to the WTC disaster and intrauterine growth retardation (35). The authors postulated that this might have been a result of maternal exposures to PAHs or other particulate matter. Similar findings recently were reported by Lederman et al. (36). They evaluated birth outcomes among non-smoking women who were pregnant on September 11, 2001 and who delivered full-term infants at any of 4 Lower Manhattan facilities. Babies born to mothers who were living within a 2-mile radius of the WTC site during the month following the disaster weighed significantly less than those of mothers who had lived elsewhere after controlling for other socio demographic and biomedical risk factors.

A telephone survey of New York City residents conducted 5–9 weeks after September 11 found that of 13 percent of the adult responders with asthma, 27 percent reported experiencing more severe asthma symptoms after the attack on the WTC. There was increased severity for those asthmatics reporting psychological distress associated with the attacks and/or difficulty breathing because of smoke and debris during the attacks (37).

A community needs assessment was performed among residents in the neighborhoods surrounding the WTC site about 2 months after September 11 (38). Over 82 percent of the adult population reported persistent respiratory symptoms that developed or worsened after the WTC attack. Nose and throat irritation was most common, followed by eye irritation or infection and coughing. An estimated 39 percent of the local residents had symptoms that indicated a potential for posttraumatic stress disorder (PTSD). About half of the population surveyed did not feel safe in their homes; they were most concerned about the air quality and potentially hazardous surface dust.

Residents living near the WTC site were surveyed to determine whether they had increases in new-onset respiratory symptoms, unplanned medical visits after September 11, new diagnoses of asthma or exacerbations of pre-existing asthma (39). Compared to residents living more than 6 miles from the site, the WTC area residents had significantly more complaints of new-onset respiratory symptoms; these symptoms also persisted in about half of those with symptoms. They were more likely to seek medical attention and to use respiratory medications. Asthmatic symptoms were exacerbated 2.4 times more in the affected area than in the population. New-onset cough, wheeze, chest tightness, and shortness of breath were the most common persistent symptoms among residents, occurring at rates 3–6 times greater than unexposed controls (39). Similarly, asthma severity increased among children with pre-existing asthma living within 5 miles of the WTC site who attended a neighborhood clinic in Chinatown, a New York City community affected by the plume following the collapse of the towers (40).

Mental health effects

Psychological and emotional effects were widespread in all segments of the metropolitan New York City population with prevalence estimates of PTSD and depression in the weeks following September 11 approximately twice the national baseline values (41). In a random sample of New York City residents Galea et al. (41) found significantly higher rates of PTSD and depression among persons who reported performing rescue work at the site than those who did not (16.2 and 14.1 percent, respectively vs. 6.4 and 9.2 percent, $p = 0.03$). However, a needs assessment conducted by Columbia University Mailman School of Public Health predicted a higher (24 percent) PTSD rate in WTC rescue workers based on an average of rates from Oklahoma City and other highly exposed populations (26). In Trout's study (10) of lower Manhattan office workers, 32 percent of New York City workers had depressive symptoms and 25 percent had symptoms of PTSD. The control population had significantly lower rates of these symptoms, with 10 percent reporting depressive symptoms and only 4 percent noting PTSD symptoms. Symptom rates also may have been affected by the extent and timing of the exposure. For example, transit workers who were evaluated over seven months after September 11 who had exposures to the dust cloud had increased levels of depressive symptoms and PTSD compared with individuals who were not in the dust cloud (42).

RISK COMMUNICATION AND DISEASE PREVENTION IN THE AFTERMATH OF THE DISASTER

Risk communication and disease prevention for disaster responders

In the immediate aftermath of the WTC disaster, efforts were initially focused on rescuing as many individuals as possible. Despite the horrific loss of life, there was successful evacuation of approximately 13,000–15,000 persons from the WTC complex. Unfortunately, in the chaos of the rescue efforts, on September 11, 2001, suitable personal protective equipment was neither widely available nor utilized by responders. Only 18 percent of FDNY responders wore respiratory protection on September 11, 2001. Similarly, the MMWR report on World Trade Center Workers and Volunteers (32) reported that only 21 percent of responders had respiratory protection between September 11 and 14, 2001.

Personal protective equipment for the first week consisted primarily of paper dust masks and N95 masks. One week later, half-face P100 non-disposable masks with replacement cartridges were available, but there was insufficient training in the use of these devices for many of the workers. A number of reports indicate that personal protective equipment was not widely used by WTC responders for many weeks, and in some cases months, after the disaster. The RAND Corporation has conducted a study for NIOSH/CDC (43) on barriers to effective responder protection in the WTC disaster. This panel is issuing recommendations designed to improve protection of disaster responder health in the event of future disasters. However, their recommendations are focused on the "traditional" responder community; further work is needed to ensure that the heterogeneous group involved in rescue and recovery in urban disasters is also adequately protected.

In addition to the lack of respiratory protection, there was a more general failure of adequate safety measures to prevent injuries among recovery workers at the WTC site. There were over 5,500 visits by relief workers to medical units on site for clinical symptoms during the period from September 14 through October 9 (44). Most of the injuries were related to mechanical factors—eye injuries, lung injury, pressure blisters and sprains and strains. The eye and lung injuries could have likely been prevented by the proper use of barrier protection in addition to respiratory protection; again, future work in preventing such conditions in the future is warranted.

Risk communication and disease prevention for residents and students

For the first week after the disaster, there was virtually no information available for residents about whether or not they should remain in their homes and about proper cleaning methods for homes. Many residents remained in the area; among 5,747 residents living south of Canal Street on September 11, 2001 who responded to a New York City Department of Health (NYCDOH)-run WTC Registry, 29 percent did not evacuate their homes. Among the 3,722 residents who told the Registry that they eventually returned, fully 38 percent returned to their homes in the first week after the disaster.

According the Environmental Protection Agency (EPA) Report of the Inspector General (45), released on August 21, 2003, the EPA announced to the public that the air was "safe" to breathe on September 18, 2001. The NYCDOH issued a press release on September 17, 2001 that recommended the use of wet rags/mops and/or HEPA vacuums for people who were re-entering either their residences or workplaces. Over a month later, on October 26, 2001, an EPA administrator recommended professional cleaning in a television interview with MSNBC; and again on December 11, 2001, the EPA posted information on its public website that recommended using professional cleaning services for indoor spaces. In February of 2002, the EPA began to assume the lead role of post-WTC clean-up of indoor air pollutants, and on May 8, 2002, the EPA and FEMA officials announced to the public a plan in which residents south of Canal Street could request free testing and cleaning of their residences. As of July 17, 2003, a total of 4154 residences were tested, of which 3,425 were cleaned (45), under the auspices of this program, and there remain concerns about the adequacy of indoor clean-up of buildings in Lower Manhattan. At the present time, the EPA has an Expert Technical Panel that is reviewing existing data on the extent of contamination of buildings in lower Manhattan and will be issuing recommendations for future action.

FUTURE RISKS—POTENTIAL INCREASED RISK OF CANCER?

There has been concern about the possibility of late-emergent disease in individuals exposed to WTC dust. Carcinogens present at the WTC site include dioxins, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, benzene, and asbestos. Exposure to some chemicals arose out of the collapse of the buildings and the dust cloud, others were related to the fires themselves, and others related to the jet fuel.

PAHs, a product of combustion, have been shown to cause cancer of the bladder, skin and lung. Benzene is associated with hematologic malignancies, notably leukemia. Dioxin exposure is associated with increased cancer mortality rate, and increased rates of soft tissue sarcoma, lymphoma and respiratory tract cancers have been seen in individuals with significant dioxin exposure (46). Liver and biliary tract cancers have been found in individuals exposed to PCBs (47). Asbestos causes lung cancer, mesothelioma, and is associated with elevated risks for colorectal cancer and laryngeal cancers. The combination of PAHs and asbestos has been shown to have a synergistic carcinogenic effect, potentially increasing the overall cancer risk of exposed individuals (19, 21, 48).

Dust from the collapse of the towers was highly alkaline; many rescue and recovery workers developed new symptoms of gastroesophageal reflux disease as a result of their exposures (27). Persistent reflux of the acidic stomach contents is a known risk factor for Barrett's esophagus, which in turn increases the risk for adenocarcinoma of the esophagus (49).

Given the complex mixture of chemicals and other compounds generated by the WTC disaster, many of which are known carcinogens, it is essential that individuals who worked or volunteered at the WTC site undergo periodic screening examinations in the future, to determine whether they have increased rates of disease and where possible to identify disease when treatable.

Chronic sequelae of current illness

Many individuals who worked or volunteered at the WTC site have new or worsening health conditions as a result of their exposures. The vast majority of rescue workers developed cough, nasal and throat irritation and gastroesophageal reflux (27) immediately after September 11, 2001. Forty percent of recovery workers had persistent lower respiratory symptoms, and 50 percent had persistent upper respiratory symptoms over a year after their exposures ceased. Reactive airways, as measured by methacholine challenge testing, have been noted in firefighters as well as other responders.

Prezant (50) found that the hyper reactivity persisted for 6 months, and actually worsened in the most exposed firefighters. It is likely that those individuals will have persistent symptoms, and fulfill the criteria for Reactive Airways Dysfunction Syndrome (51) or asthma without latency. Many individuals seen in the WTC Worker and Volunteer Medical Screening Program continue to have upper and lower respiratory symptoms (32). A significant number of workers and volunteers at the WTC site have persistent mental health symptoms, including PTSD and depression (52). Given that many of these symptoms have persisted for over 2 years, it is likely that many of these individuals will continue to have difficulties in the future.

Prevention of late emergent diseases

From the studies of rescue and recovery workers that have been conducted thus far, it is clear that there are persistent health effects. A critical issue remains for the future—How can we best prevent future health problems?

Certainly, it is crucial to provide medical monitoring examinations for those individuals who had the greatest potential exposures—the rescue and recovery workers. The use of screening tests for preventable cancers, such as colon cancer and skin cancer should be performed. Routine health maintenance and vigilance for early detection of other cancers such as lung, esophageal and bladder cancer must be conducted. Aggressive treatment of GERD may prevent future cases of esophageal cancer. Smoking cessation should be strongly encouraged among WTC responders, and incorporated into all future monitoring programs. If improvements are made in lung cancer screening—for example, if low dose chest computed tomography (CT) scans prove to improve survival—this should be offered to rescue and recovery workers in the future.

Initiatives for the future

In 2004, the National Institute for Occupational Safety and Health funded an additional 5 years of medical monitoring examinations for rescue and recovery workers. While this is critical to enable investigators to describe the current health status of these individuals, it will be necessary to follow these workers for many years to come. Cancers that might be related to the WTC, for example, are not expected to manifest for 20 years or more. Difficulties with estimating the full extent of WTC health effects may occur due to the healthy worker effect, which might lead to fewer cases of disease than might be expected.

Greater preparation for future disasters is essential. The lack of any air quality standards for acute exposures remains problematic—if such standards existed in 2001 it is likely that the air quality would not have been considered "safe"—this pronouncement was based solely on ambient air asbestos concentrations (45). Much of the initial focus on health effects centered on asbestos exposure; symptoms related to asbestos will not become evident for decades. On the other hand, the acute effects of dust and fumes had immediate and persistent health problems, which were often neglected, and individuals were not educated that these health concerns might have been WTC related. It is also important to educate health professionals on possible illnesses that might instigate prompt, appropriate care.

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