Commentary

Lessons Learned on Environmental, Occupational, and Residential Exposures From the Attack on the World Trade Center

Paul J. Lioy, PhD,* **and Michael Gochfeld,** MD, PhD

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INTRODUCTION

The aftermath of the attack on the World Trade Center (WTC) has been a very challenging time for our Nation. The events on September 11, 2001 resulted in a rescue effort lasting for several weeks, and a recovery and demolition operation that lasted until May 30, 2002. The magnitude of the physical hazards and challenges posed by the structural debris at ground zero, initially detracted attention from the complex environmental hazards facing the emergency responders, rescuers, construction workers, and site neighbors. Related issues include post-traumatic stress disorder [Kipen and Gochfeld, 2002], and the potential acute and chronic effects caused by the dust/smoke [Lioy et al., 2002].

OUTDOOR ENVIRONMENTAL EXPOSURE MONITORING

Sampling at Ground Zero itself was hindered by the general chaos and uncertainty, the intense fires, and its treatment as a crime scene. Industrial hygiene and spot environmental measurements, mainly for asbestos, were begun immediately by Con Edison and the Occupational Safety and Health Administration (OSHA). At first, only asbestos was measured because it had been used to fireproof part of the North Tower. The United States Environmental Protection Agency's (EPA) Office of Emergency Response began integrated monitoring for volatile organic compounds (VOCs), which are typically released during fires or by evaporation, the refrigerant Freon [EHP, 2001], and particulate matter (<2.5 and <10 μm in diameter) at three sites surrounding Ground Zero, and at one off site location on September 15, 2001. State and city routine air monitoring stations operated during and after the collapse [US EPA, 2002, Status Report-Personal Communication]. The NYC Health Department, and OSHA monitored site workers. Additionally, during the first days, outdoor settled dust/smoke samples were collected by the US EPA, the Environmental and Occupational Health Sciences Institute (EOHSI), UMDNJ-Robert Wood Johnson Medical School, and the New York University Institute of Environmental Medicine.

The measurement of gaseous and particulate products of incomplete combustion was hampered by a number of factors. Initially, there was the lack of electricity to run samplers. There were an inadequate number of quasi-continuous or continuous samplers, and the high mass concentrations in the local atmosphere during the initial days quickly overloaded standard air monitors.

Of the samples collected by EOHSI, each was examined for general size, morphology, asbestos, pH, and/or inorganic and organic components. Most of the material was >10 μm in diameter which is in the inspirable particle range. These particles would be captured in the upper airways while

Environmental and Occupational Health Sciences Institute, UMDNJ-Robert Wood Johnson Medical School, Piscataway, New Jersey

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*Correspondence to: Paul J. Lioy, EOHSI, 170 Frelinghuysen Road, Piscataway, NJ 08854. E-mail: plioy@eohsi.rutgers.edu

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FIGURE 1. Indoor deposition of dust and smoke that was released by the collapse of the WTC.

thinner fibers would travel deeper into the respiratory system. We have reported that the glass fibers had smaller particles of cement and other debris agglomerated along their surface [Lioy et al., 2002]. Elevated levels of dioxins were found in other dust/smoke samples (Vette A, 2001, Personal Communication). Dust on indoor surfaces sometimes exceeded 10 mm deep and posed immense challenges for reoccupation. The samples included glass fibers, lead, polycyclic aromatic hydrocarbon, and phthalates. These results were important as they pointed to materials that could lead to acute or long-term health effects, understanding the nature of these materials helped in evaluation of the ''World Trade Center cough'' and later in recommendations for indoor cleanup.

Lessons Learned

Based upon the above facts, improving data collection in an emergency should include development of: (A) improved portable and flexible emergency response monitors. Air samplers need to be battery operated, since sources of electric power may not exist. The monitors should be designed to measure a wide range of particles and gaseous substances, including those *not* routinely measured by local agencies. The sampling devices also must be lightweight and manageable in size, and have a goal of providing real-time data continuously. Samplers designed for use in mines would be a starting point for designing improved samplers for high ambient or indoor air exposure events [ACGIH, 2001]. (B) Strategies for the rapid acquisition of settled particulate material samples in catastrophic events that yield resuspendable dust/smoke. Samples should be analyzed for materials that could cause acute or long-term health effects. At the WTC, it became apparent that materials other than asbestos were of concern, for example, lead, phthalates, and glass fibers, and (C) a rapid method for determination of site-specific and event-specific analytes that could cause acute or chronic effects. Selection should be based on an immediate assessment of the nature of the event, for example, fire, explosion, building collapse, chemical or biological release, and the characteristics of damaged buildings and of the neighborhood. (D) Efforts at Ground Zero were also hampered by destruction of the New York City command post and the loss of blueprints for the WTC complex, which had been stored on site. Building plans should be stored at multiple and remote locations.

Recommended Approach

We urge development of a toolbox of techniques for portable, durable, and multiple pollutant monitors for use in community-based emergency response situations, with rapid turn-around time, yielding exposure data almost immediately. The techniques should be relatively simple, but capable of measuring a variety of toxicants that cause acute and chronic effects. A framework is also needed to quickly prioritize and re-assess these exposures. In an emergency, the number of toxicants may be many or few; decisions, however, can still be made on the level of personal protection needed and re-entry criteria.

EMERGENCY RESPONSE STANDARDS

The events of September 11 demonstrated a need to establish ''emergency response standards'' that would protect workers and site neighbors in an affected area, and to identify criteria for recommending evacuation or re-entry of outdoor and indoor locations. At the WTC, agencies used whatever standards were available to determine the safety of the environment. In retrospect, the initial concerns should have focused on the dust/smoke as they had an immediate impact on acute health outcomes of site workers.

Communication of standards became an important issue. Workers and community residents received information from agencies and the media regarding some exceedences of the occupational permissible exposure limit (PEL) for asbestos. However, it was seldom made clear that the PEL is based on a 40 hr work week and a 40 year working lifetime, and that brief exposures in excess of the PEL are undesirable, but not devastating. Although the OSHA field staff were familiar with this issue and tried to explain it, some personnel and spokespersons from other agencies were not clear on this distinction.

Lessons Learned

A variety of emergency response standards for community evacuation, worker re-entry, and residential/commercial re-entry, in various community or occupational zones at increasing distances from a disaster site must be developed. Short-term exposure standards for establishing evacuation and restricted entry zones, and determining an ''all clear'' must be based on potential acute health outcomes (lethal and/or sub-lethal effects). This would determine the types and levels of personal protection, re-entry time, and cleanup instructions.

Recommended Approach

These standards could be patterned after or utilize the US EPA's National Advisory Committee for Acute Exposure Guideline Levels (AEGL) to hazardous substances [NRC, 2000]. AEGL values would serve as threshold levels for no-effect and one or more health endpoints, or biological reference values for many acute toxins. Degrees of hazard need to be presented to determine the level and severity of concern or the ability to return to a particular location after cessation of an event or cleanup. Training for personnel from all agencies on the differences between acute and chronic standards would clarify that many standards (e.g., OSHA's PEL, US EPA's Reference Dose) are based on risk estimates from long-term (40–70 year) exposure. This training should make it clear that it is desirable to reduce all unnecessary exposures, while at the same time not becoming fearful about short-term exposures, particularly to non-carcinogens. This information must be shared with the media.

INDOOR ENVIRONMENTAL CLEANUP

During one of our visits to Ground Zero on September 17, 2002, we noted that the indoor environment of partially damaged structures and intact buildings would present a long-term challenge (Fig. 1). There did not seem to be any specific agency in charge of the indoors environmental issue. In fact, no federal agency had the clear authority to go in and measure the nature or magnitude of the initial problem in neighboring residences. This responsibility seemed to fall on the building owners or occupants. Unfortunately, these groups had a conflict of interest as they were anxious to re-enter buildings for residential or commercial purposes with minimal delay, but could not appreciate and interpret information on exposure and possible hazards. One of the most aggressive building occupants was Verizon, which started indoor monitoring on September 13, 2001; however, they only monitored for asbestos. In late November, weeks after many of the buildings and apartments had been re-occupied; the Agency for Toxic Substances and Disease Registry (ATSDR) completed an indoors environmental sampling program. By May 2002, there were many re-occupied buildings, which had not been adequately cleaned. Initially, citizen's concerns focused on asbestos, which was widely reported in the media, as ranging from non-detectable to $>3\%$ by mass in dust samples [EHP, 2001; Lioy et al., 2002]. Indoor exposure to asbestos does indeed pose a significant health threat [Gochfeld, 1995], but other mineral fibers, including those substituted for asbestos can be hazardous as well [Brooks, 1995].

The EPA realized that tracking outdoor contamination into cleaned buildings, streets, and sidewalks was a source of settled dust. It had to be cleaned up prior to cleanup indoors, because without a thorough outdoor cleanup, indoor cleaning was impossible. The outdoor cleanup in public areas and at Ground Zero proceeded slowly, but effectively. However, the removal of dust from the outdoor surfaces on private buildings (e.g., rooftops and lobbies) was haphazard and not always complete. This was due in part to the lack of an agency clearly in charge of financing and directing indoor environment efforts, and the lack of rules for cleanup. This uncertainty severely affected resident or building owner decisions about the type of cleanup, including the need to have a hazardous material cleanup for lead and asbestos in offices and residences. The above was conveyed to the public repeatedly by US EPA, NIEHS, and others but was not effectively received by local stakeholders or was lost in the

WTC information overload. Moreover, even residents and owners who received adequate information about the scope of indoor cleanup required for ''safe'' re-entry faced difficult decisions. Many people simply cleaned up dust and debris as if there were no hidden health hazards, using dry methods and dust masks for protection. Others expanded their efforts to include wet methods. Many occupants sought services of commercial cleanup firms. However, the magnitude of the devastation required these firms to hire inexperienced workers, many of who were not adequately trained either in self-protection or in cleanup. Moreover, the costs of cleanup had to be borne entirely by the occupants or owners. In May 2002, the US EPA gained authority, responsibility, and funding to conduct voluntary cleanup of residences. This unprecedented effort will require detailed but implementable strategies for cleanup of occupied or re-habitable buildings. Efforts should be made to achieve total participation in each building.

Lessons Learned

The only agency authorized for indoor cleanup and re-entry was the local health department, which did not have the resources to conduct or facilitate cleanup. A formal post-disaster cleanup protocol needs to be developed and validated for indoor settings, and a lead agency must be identified to implement the program so that cleanup can proceed without delay. For floods, and other natural disasters, Federal Emergency Management Administration (FEMA) is in charge, and it should have been prepared for dust/smoke released by the attack on the WTC. A set of residential dust/smoke clearance levels needs to be developed to permit safe re-entry after cleanup: including, a policy on the types of personal effects (e.g., toys, furniture, cars) to be replaced because of irreparable contamination (e.g., lead, asbestos). The nearly nine-month lag between September 11, 2001 and EPA's authorization to fund residential cleanup should not occur in the future.

Recommended Approach

Our government must expeditiously assess its response to community-wide indoor air and settled dust issues during post disaster emergencies. There needs to be an identifiable lead agency. It should be in charge of identification of the toxicants of concern, should set acceptable ''post remediation'' residual levels, should select the cleanup or remediation strategy, implement cleanup, and conduct pre- and post-cleanup monitoring for contamination and re-entry. In a security disaster of the scale of the WTC, a clear route to access emergency funding for immediate cleanup must be outlined. Procedures are needed for the systematic cleanup of an entire building (e.g., facade, roofs, ventilation, entryways, rooms).

RESPIRATORY PROTECTION

For many years, the occupational hygienist, the hazardous waste worker, and the emergency responders have dealt with personal protection issues. OSHA has recently revised its Respiratory Protection Standard [OSHA, 1910.134; www.osha.gov]. The preamble to 1910.134 emphasizes the primacy of controlling airborne hazards in the work environment: "... by accepted engineering control measures." However, outdoor work in the aftermath of the WTC collapse precludes environmental control. The contaminated environment becomes the workplace, and personal protection comes to the forefront.

Respiratory protection devices have been developed for particulate matter or gaseous substances. They range from paper dust masks to self-contained breathing apparatus. An elaborate respiratory protection scheme exists, largely codified in 1910.134. NIOSH is responsible for evaluating and certifying respirators. Criteria for selection of respiratory protection are found in NIOSH documents and in industrial hygiene texts [Plog and Niland Jm Quinlan, 1996], and the elements of a respiratory protection program can be found in many of these documents.

Throughout the WTC rescue and recovery operations it was clear that many firefighters, volunteers, outdoor and indoor cleanup workers, did not wear their respirators, while others appeared to be wearing equipment improperly. When the priority was to find and extract survivors, it was apparent that full compliance with the standard would not be achieved. Nonetheless, it was during this phase that workers experienced their highest potential for inhalation exposures. Reasons given were that the respirators were uncomfortable and unmanageable during such operations. To some extent this would have been ameliorated with an aggressive and uniform respiratory protection program. In a study by Salazar et al. [2001], they found that participation in fit testing and training enhances the likelihood that waste workers will use their respiratory protective equipment appropriately. Not surprisingly, workers reported that discomfort and/or interference with communication or visual field reduced likelihood of respirator use, while certain structural environments (the WTC would have been a prime example), also made respirator use impractical. Their work confirms that merely making respirators available is not sufficient to assure their use. Within one week, abundant respirators were on hand in the supply depot, and we observed a wide variety of twin cartridge and canister respirators with and without full-face masks. However, no instructions were provided to help WTC workers select the correct respirator, nor was fit testing conducted until day 3. Moreover, our visit to Ground Zero on day 6 revealed that although about half of the field personnel actually had respirators draped around their neck, virtually no one was using them. Many of the emergency responders and probably many of the construction workers had had some prior training, which would have included respirator use, but clearly there was no site or contaminant-specific information. By the end of week 2, there was a respirator fit testing program. In addition, the worker population changed during recovery. ''Volunteers'' declined, and were replaced by contracted workers for whom participation in the respiratory protection program was required. Nonetheless, the number of site workers who wore respirators was $<50\%$, and even trained firefighters did not achieve full use of respirators. Unfortunately, the subsequent prevalence of upper respiratory irritation and ''WTC cough'' reflects the irritating, high pH, nature of inhaled particles breathed by poorly protected workers.

We see three reasons for this non-compliance: (1) a psychological perception, particularly in the rescue phase, that protecting oneself was somehow inappropriate, (2) a risk perception that the environment was only smoky and irritating, and not really hazardous to health, and (3) a physical perception that the discomfort, inconvenience, and interference by the respirator exceeded any benefit. We cannot comment on the psychological perception, and the risk perceptions were confused by ambiguous and conflicting reporting of environmental data. The physical aspects of respirator design are constantly evolving, usually to improve fit and protection. For first responders, however, the designs must also include comfort and convenience, including what we call ''the feel of the seal,'' the weight, and communication channel. In the chaotic rescue phase of WTC when many operators of equipment worked at the site, with trucks coming and going, the need to be able to communicate clearly is paramount. Future respirators also need to allow expression of clear and loud vocal commands.

Lessons Learned

In the event of a natural or security emergency response situation workers must be protected against one or more substances. Merely making respirators available does not assure their use. However, to implement such a program research needs to be conducted on the design of a respirator to ensure that emergency responders use respiratory protection, and use it in the correct manner. Many of the non-air pack respirators are heavy and not easily worn over the nose and mouth during complex task operations.

Recommended Approach

''Although options may be limited in a disaster, a generic Respiratory Protection program can be made available. It will provide guidelines for obtaining and distributing equipment in a timely manner, and will provide for iterative changes in equipment as new information on contaminant levels becomes available'' [Salazar et al., 2001]. The basic features of masks and respirators have been standardized, but we need to design new equipment that can accomplish a high level of protection while being less cumbersome to wear. We recommend initiating a research and development program to design a respirator, or a series of respirators that are for use in short-term rescue and recovery operations that do not require an air pack or supplied air. Such a system should fulfill the four ''c's'' of being cheap, compact, comfortable, and convenient.'' ''Cheapness'' allows equipment to be discarded; eliminating the need for cleaning and maintenance, which may be difficult in chaotic situations.

CONCLUSIONS

The United States has a long history of civil defense and emergency response, dating back at least to World War I. In 1950, President Truman created the Federal Civil Defense Administration with a mission to prepare for large-scale nuclear attack. By 1979, in a nation inured to the Cold War, Civil Defense was transformed into the FEMA, to focus attention on other very real disasters. Under the 2000 amended Stafford Act, FEMA is primarily focused on natural disasters. This mandate was interpreted as precluding involvement in residential cleanup, and the lack of authority over rented space by any agency precluded cleanup of multi-user commercial and residential buildings.

Further, ''preparing for the unimaginable?'' has become a watchword among governmental and non-governmental agencies. Issues of infrastructure, evacuation routes, emergency triage, and medical care, are ripe for discussion and agencies are competing for priorities and funding. The bioterrorism event that followed the WTC disaster heightened the sudden sense of vulnerability and paved the way for funding of emergency response and management initiatives. We think that the WTC disaster and the rescue, recovery, and remediation highlight the necessity for environmental preparedness as well. The environment in which workers and volunteers labored and to which business people and residents returned, contained material that threatens health and created symptoms with potential long-term effects. Many groups participated in the effort to assess hazards and minimize long-term risks. The above lessons identify ways to improve our response should another ''unimaginable'' event occur; although, the toxicants may be different.

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