World Trade Center cough

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The devastating collapse of the World Trade Center on Sept 11, 2001, had unprecedented implications for the environment. The collapse released millions of tonnes of material into the air from pulverised and incinerated building materials, furniture, equipment, and unburned jet fuel. The dust cloud from the collapse enveloped a large area around the World Trade Center, and penetrated many buildings in lower Manhattan. Additional pollutants were released by the ensuing fire, which persisted until Dec 20, 2001, and by the recovery and clean-up processes, which continued until the middle of 2002. Immediately after the collapse, thousands of survivors, residents, workers, students, and commuters, along with policemen, firemen, health-care workers, and civilian volunteers, were exposed to high concentrations of gaseous and particulate matter air pollution, including soot and dust.

We felt it was critically important to characterise the particle exposure environment with respect to the chemical nature and health impact of particles that existed immediately after the collapse, and to examine the continuing air quality concerns around the World Trade Center. The findings from these studies may facilitate early detection of potential health effects. One of the main mysteries surrounding this pollution was the "World Trade Center cough" that was reported by many local residents, in apparent conflict with many government pronouncements of "safety" in the days after the disaster. Our environmental measurements provide a possible explanation for this disparity between the government reassurances and the symptoms reported by local residents, workers, students, and World Trade Center workers.

Images of dust-covered survivors, firefighters, and rescue workers immediately raised our concerns of the health consequences of exposure to an enormous concentration of dust, which may have contained toxic material. For example, although most World Trade Center buildings did not use asbestos, the lower floors were built before a rule against its use was in place, so asbestos was a possible concern. Other compounds of potential concern were fibreglass, dioxin, and other chlorinated compounds (eg, from the burning of plastics), freon, heavy metals, and volatile gases (eg, benzene) from building materials soaked in jet fuel. At the immediate urging of the US National Institute of Environmental Health Sciences, we sent a team of technicians and students to collect dust samples at a number of locations in the area immediately adjacent to the World Trade Center site, and at nearby sites in lower Manhattan east, west, north, and south of the epicentre (Ground Zero) on the days after the collapse. All samples were collected from undisturbed surfaces, such as the top of a car, windowsills, or on sidewalks. The locations where we collected these dust "fallout" samples are displayed in the map.

Although most governmental agency and other research efforts centred on Ground Zero, we focused on community exposures to the particle pollution emanating from the site fires; the resuspension of settled dusts during rescue, recovery, excavation, and clean-up activities; and from the combustion particles produced by the diesel trucks at Ground Zero. We therefore set up an air quality monitoring station at a nearby hospital to measure ambient particulate matter concentrations in the community. These detailed ambient air measurements included hourly elemental carbon soot, the mass of particulate matter less than 10 μm in diameter, the concentrations of airborne particulate matter smaller than 2·5 μm in diameter, and data from a size-fractionated mass impactor. The samplers were located at New York University Downtown Hospital, which was ironically established in response to a terrorist attack in the financial district on Sept 16, 1920. These particulate matter samples have since been analysed for their constituents to determine the metal and organic contents after the collapse.

The US Environmental Protection Agency also started collecting samples of particulate matter around Ground Zero, including many measurements of ambient asbestos. Although the agency focused its measurements of the mass of particulate matter on the usually most toxic smaller particles (<2·5 μm), our analyses were more expansive, looking at the characteristics of the dust and

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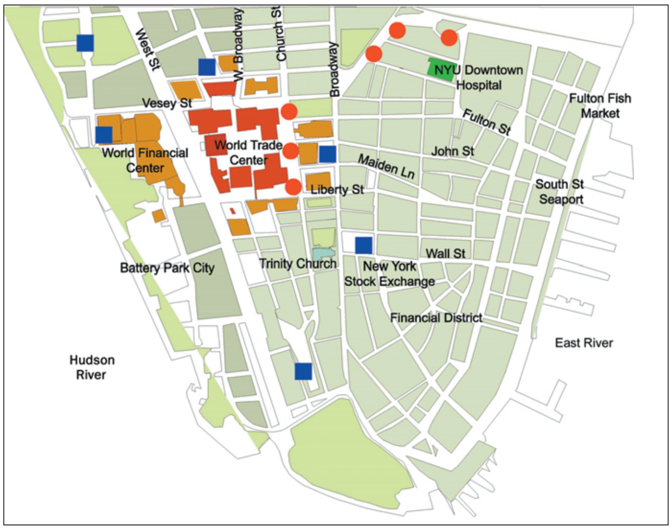
airborne particles in a wider range of sizes. This turned out to be the key to our present understanding of "World Trade Center cough".

Probably the most important variable related to particle exposure is particle size. Particles larger than 10 μm are usually captured in the nose and throat before they get to the lungs. Particles between 2·5 μm and 10 μm will deposit in the lungs' upper airways, whereas particles smaller than 2·5 μm will be breathed into the deepest (alveolar) regions of the lungs. Our results showed that more than 95% of the dust particles' mass was larger than 10 μm in diameter, with more than 50% larger than 53 μm. The government did not measure these larger particles because they are not regulated routinely.

As expected, the fraction of particles larger than 53 μm was much smaller for dust that infiltrated indoors than for outdoor dust samples. Thus, we identified more particles between 10 μm and 53 μm in the indoor samples than in the outdoor samples, but in both cases almost all the dust would be caught in the nose, throat, and upper airways, rather than reaching deep in the lungs. Thus, the natural defences designed to protect the deep lung worked well against the World Trade Center dust, but resulted in the potential for high dust exposures to residents' noses and throats.

We also assessed every size-fraction of the dust for composition, including concentrations of asbestos, water-soluble ions, toxic elements, and polycyclic aromatic hydrocarbons. We first examined the dust under a light microscope. Most of the mass was fibrous and composed of many different types of fibres (eg, fibreglass, wool, wood). The content and distribution of material were consistent with the complex building debris. The compositions of major components were similar between samples collected at different locations, indicating that World Trade Center dust was distributed uniformly throughout lower Manhattan. Only trace amounts of asbestos were found in these samples. This result is consistent with the results reported by the Environmental Protection Agency, which, of the thousands of asbestos samples collected, found only about a dozen samples with daily concentrations above a very restrictive guideline based on long-term asbestos exposure standards.

One property of the dust that probably contributes to its irritancy is its caustic nature. The pH of most of the suspensions of the bulk World Trade Center settled dust was greater than 10, which is irritating to mucous membranes. However, the dust's alkalinity decreased with decreasing particle size, with particles less than 2·5 μm at about neutral pH. The caustic, alkaline large particles and large fibreglass fibres that were caught in the eyes, nose, and throat were probably responsible for the chronic cough of the residents and workers near Ground Zero. Thus, although the caustic large dust particles caused temporary nose, throat, and upper airway symptoms, they were effectively caught by the body's defences. Conversely, the fine dust that did reach the deep lung was lower in concentration and much less caustic. Therefore, although the public had severe acute symptoms, the overall dust exposures probably did not have many cumulative health implications for the general population in lower Manhattan, as long as their indoor spaces had been properly cleaned.



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Lower Manhattan, New York: red circles, samples gathered on Sept 12, 2001; purple squares, samples gathered on Sept 13, 2001

There are important public health lessons to be learned from this disaster. Overall, we found that, as was reported by the Environmental Protection Agency, there were few violations of the 24-h fine particle standard (65 μg/m^3) in the weeks after September 11, but there were higher brief (eg, 1 h) peaks in concentrations of very fine particulate matter in the area near the World Trade Center that probably had short-term effects on the health of especially susceptible people (eg, the very young, older adults, and people with pre-existing respiratory or cardiac disease). However, most symptoms in the general population were apparently related to the larger, unregulated, alkaline dust particles. These large particles did not penetrate deep in the lung to ultimately have severe or long-term health implications, but were very alkaline and irritating, causing obvious respiratory symptoms. The differences in the characteristics of small and large particles could explain why the government declared the outside air "safe" even though the public had eye, nose, and upper airway symptoms. Should such disaster situations occur in the future, it seems clear that government agencies should make wider assessments of exposure before making pronouncements and should avoid any broad assurances of safety to the public before all the facts are known. Even when the government is basically right, as it apparently was in this situation, premature assurances of safety tend to undermine, rather than increase, public confidence.

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