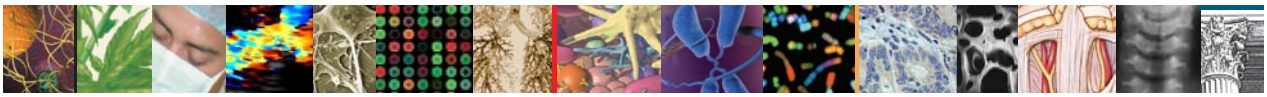

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Perspective

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The Legacy of World Trade Center Dust

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More than 5 years after the World Trade Center disaster on September 11, 2001, uncertainty and controversy remain about the health risks posed by inhaling the dust from the collapse of the twin towers, the subsequent fires, and the cleanup effort. In addition to the matter of the immediate and persistent respiratory effects on "first responders," occupants of the towers, cleanup workers, and neighborhood residents, concern has arisen about longer-term risks, including the risk of cancer. The level of concern with regard to the respiratory effects of the disaster may well be compounded by the psychological consequences. Already, some responders have received compensation, and litigation is in progress for thousands of people with alleged illnesses caused by inhaling the dust.

With the collapse of the towers, the air at ground zero became heavily contaminated. Subsequently, the smoke and dust from fires and resuspended debris and the engine exhaust from cleanup equipment and vehicles were major sources of airborne contaminants.[1] Because air was not sampled immediately after the disaster, data are lacking on the identity of the contaminants and their concentrations in the plume at that time. Photographs showing a dense cloud at street level imply that the concentrations of particles in the air must have been on the order of milligrams per cubic meter — orders of magnitude greater than typical ambient levels. Analyses of settled dust samples revealed the presence of combustion-related carcinogens, building materials, and some asbestos. The samples were dominated by larger particles, which settle more quickly than smaller ones. The smaller particles, which can penetrate into the deep lung and would have been generated by burning materials, were probably not captured in these samples.

Soon after the disaster, agencies and academic institutions implemented monitoring for particles, volatile organic compounds, polychlorinated biphenyls, and dioxins and metals associated with particles. The composition of the mixture changed as debris removal progressed and as fires were extinguished. Analyses of archived filters for carcinogenic polycyclic aromatic hydrocarbons (PAHs) indicated very high concentrations from fires in the early days and lower levels later, probably from diesel engines. In October 2001,

Firefighters at Ground Zero in the Early Weeks after the Attacks.

samples collected from streets bordering the disaster site showed high concentrations of particulate matter less than 2.5 μm in aerodynamic diameter; by April 2002, the median concentrations had decreased substantially.[2] Even at far lower levels, exposure to airborne particles in U.S. cities has been linked to premature death and disease. The characteristics of the particles present at the time of the disaster were undoubtedly quite different from those in typical urban air pollution, but without specific estimates of exposure for workers and the population, the risks from these materials cannot be quantified.[1]

The risks posed by exposure to airborne particles depend on the doses delivered to the respiratory tract. Particle size is also key: particles larger than 5 μm are effectively filtered out by impaction in the upper airways, unless concentrations are high. Smaller particles penetrate the lungs, and nanosized particles generated by combustion can be deposited throughout the respiratory tract. It is likely that particles of all sizes were initially present in the dust at very high concentrations that decreased over time.[1] A biomonitoring study of firefighters suggests that they may have received substantial doses of larger particles.[3] Analysis of induced sputum collected from involved firefighters 10 months after the disaster showed a significantly higher percentage of large mineral particles than that found in a comparison group of firefighters from Tel Aviv. Irregularly shaped particles were seen in epithelial cells and alveolar macrophages, and their mineral content, unlike that in the comparison group, included such elements as gold, tin, and titanium. A correlation was reported between the estimated level of exposure to this dust and markers of inflammation in the firefighters.

Little is known about the extent to which the workers and the general population were exposed to the potentially toxic gases generated by combustion, such as dioxins. An analysis of 110 chemicals in blood taken from firefighters in early October 2001 showed elevated levels of 5 chemicals.[4] This study showed that firefighters at the site received elevated doses of some PAHs, which suggests they may have inhaled other combustion carcinogens.

Controversy continues concerning the extent of asbestos exposure among workers and the general population. The Environmental Protection Agency collected thousands of samples of airborne and settled dust and analyzed them for asbestos content. The majority of samples had an asbestos content below the clearance threshold used for schools. Some workers at the site probably inhaled asbestos fibers, particularly if they were not wearing protective equipment. The level of asbestos exposure among people living and working around the site was probably lower and is unlikely to have been sufficient to cause asbestosis or a measurable increase in the risk of lung cancer. Although such exposure might slightly increase the risk of mesothelioma, any excess would not become evident for decades.

The initial assessment and follow-up of firefighters have shown that a syndrome described in the *Journal* in 2002 as "World Trade Center cough" developed in some firefighters and that exposure was associated with a substantial and probably permanent loss of lung function. Physiological testing of exposed firefighters about a month after September 11 showed that the level of bronchial hyperreactivity in those who were on site the morning of the disaster was three times that in those who arrived later but within the first 2 days. Pulmonary instillation of World Trade Center dust into mice also induced bronchial hyperresponsiveness.[1] The clinical picture in the firefighters is consistent with that of reactive airways disease, which can develop after

high-level — and often brief — exposure to inhaled irritants. Follow-up of firefighters during the year after the disaster showed a reduction in lung function about 10 times as severe as that predicted for a single year of aging — a drop of approximately 320 ml in the forced expiratory volume in 1 second, as compared with the normally anticipated drop of 30 ml. Medical monitoring for up to 12 months after the towers' collapse showed persistent respiratory abnormalities in responders.[5]

The general population would have been exposed to particles and gases when on or near the site on days when the air was polluted by the fires or cleanup activities or when returning to contaminated buildings. Many survivors of collapsed or damaged buildings reported new or more severe respiratory symptoms several years after the disaster. One survey, started 8 months after the disaster, found greater respiratory morbidity and more symptoms among people living within 1.5 km of the site than among those in a control area.[1]

Some conclusions can now be reached about the World Trade Center dust and its associated risks. First, the dust has been described thoroughly, and uncertainty concerning exposure levels and the characteristics of the mixture will not be reduced. Second, some responders who were at the site in the hours and days immediately after the disaster have persistent respiratory abnormalities consistent with airway injury resulting from inhaled particles and gases. Medical monitoring has been put in place for this group. They were exposed to inhaled carcinogens, but any associated increased risk for respiratory tract cancer and most other types of cancer will not become apparent for decades. Some reassurance can be found in studies of other firefighter groups that have generally not shown a high risk of respiratory tract and other cancers. Third, the respiratory health of the general population, particularly those who were in collapsed or damaged buildings, may have been affected. Synergy among the inhaled pollutants, together with psychological sequelae reflecting the severity of this extraordinary event, may also have contributed to the occurrence and persistence of symptoms.

A Truck Receiving a Load of Debris for Removal from the World Trade Center Disaster Site.

As people who were exposed to the dust age and develop malignant and nonmalignant respiratory diseases as a result of smoking and other factors, some will undoubtedly attribute these diseases to their exposure at ground zero. The actual causal contribution of the dust to future risk of disease can best be characterized through prospective epidemiologic investigations involving sufficient numbers of exposed persons, along with control groups. A World Trade Center Health Registry has been established and includes survivors of collapsed and damaged buildings in downtown Manhattan and the immediate vicinity of the disaster site; rescue, recovery, and cleanup workers; and students and staff members at downtown Manhattan schools. The registry, designed to track the physical and mental health status of this group of highly exposed persons for up to 20 years, could become the platform for the requisite investigation. Decades of commitment to the registry, as well as continued monitoring of responders, will be needed to gain the best information possible on the longer-term consequences of inhalation of the dust.

Still, there are some things we will never know for certain; indeed, we do not even know with any certainty the size of the exposed population. Continued tracking of the responders should provide a clearer picture of the natural history of World Trade Center cough syndrome and should guide selection of the most effec-

Equipment Operators Remove Debris From a Mountain of Rubble.

tive therapies. The registry will be informative regarding broad questions of health, but although it includes more than 71,000 registrants, analyses of follow-up data will not reveal the existence of relatively infrequent consequences unless the additional risks are very high. The long-term risks of cancer will be difficult to measure with any precision, although quantitative risk-assessment approaches should prove useful for estimating the maximum potential burden of cancer. But even the full suite of research efforts in progress may never provide the evidence needed to answer all the questions that will be raised about the long-term health effects of the events of September 11.

An interview with Dr. Robin Herbert, codirector of the World Trade Center Medical Monitoring Program at Mount Sinai Hospital, New York, can be heard at www.nejm.org.

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Drug Risks and Free Speech — Can Congress Ban Consumer Drug Ads?

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In 2004, the discovery that Vioxx (rofecoxib) was a risky drug put direct-to-consumer pharmaceutical advertising in the spotlight. The image of Dorothy Hamill lacing up her skates and gliding over the ice despite her osteoarthritis offered a disturbing contrast to the public realization that millions of patients who were lured by the ad into taking Vioxx were risking stroke or myocardial infarction. Now, 3 years later, legislation that — if it is not amended, as some legislators want — would allow the Food and Drug Administration (FDA) to block direct-to-consumer ad campaigns for new drugs has been introduced in Congress (see graph). There is popular support for a ban: in a telephone survey conducted in March 2007 by *Consumer Reports*, 59% of respondents "strongly agreed" that the FDA should ban advertisements for drugs that had safety problems. But some legal scholars believe that such a ban would be overturned by the courts as unconstitutional. If Congress wants to turn its proposals into law, said Robert Post of Yale Law School, it needs to find a different way of approaching the issue.

The authority to ban direct-to-consumer advertising is included in two drug-safety bills that have