

## The World Trade Center Disaster and the Health of Workers: Five-Year Assessment of a Unique Medical Screening Program

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**BACKGROUND:** Approximately 40,000 rescue and recovery workers were exposed to caustic dust and toxic pollutants following the 11 September 2001 attacks on the World Trade Center (WTC). These workers included traditional first responders, such as firefighters and police, and a diverse population of construction, utility, and public sector workers.

**METHODS:** To characterize WTC-related health effects, the WTC Worker and Volunteer Medical Screening Program was established. This multicenter clinical program provides free standardized examinations to responders. Examinations include medical, mental health, and exposure assessment questionnaires; physical examinations; spirometry; and chest X rays.

**RESULTS:** Of 9,442 responders examined between July 2002 and April 2004, 69% reported new or worsened respiratory symptoms while performing WTC work. Symptoms persisted to the time of examination in 59% of these workers. Among those who had been asymptomatic before September 11, 61% developed respiratory symptoms while performing WTC work. Twenty-eight percent had abnormal spirometry; forced vital capacity (FVC) was low in 21%; and obstruction was present in 5%. Among nonsmokers, 27% had abnormal spirometry compared with 13% in the general U.S. population. Prevalence of low FVC among nonsmokers was 5-fold greater than in the U.S. population (20% vs. 4%). Respiratory symptoms and spirometry abnormalities were significantly associated with early arrival at the site.

**CONCLUSION:** WTC responders had exposure-related increases in respiratory symptoms and pulmonary function test abnormalities that persisted up to 2.5 years after the attacks. Long-term medical monitoring is required to track persistence of these abnormalities and identify late effects, including possible malignancies. Lessons learned should guide future responses to civil disasters.

**KEY WORDS:** air pollution, disaster response, occupational lung disease, pulmonary function, September 11, spirometry, World Trade Center. *Environ Health Perspect* 114:1853–1858 (2006). doi:10.1289/ehp.9592 available via <http://dx.doi.org/> [Online 6 September 2006]

An estimated 40,000 men and women worked at Ground Zero, the former site of the World Trade Center (WTC) in New York City, and at the Staten Island landfill, the principal wreckage depository in the days, weeks, and months after 11 September 2001 (Levin et al. 2004). These workers and volunteers included traditional first responders such as firefighters, law enforcement officers, and paramedics, as well as a diverse population of operating engineers, laborers, ironworkers, railway tunnel cleaners, telecommunications workers, sanitation workers, and staff of the Office of the Chief Medical Examiner. These men and women carried out rescue-and-recovery operations, restored essential services, cleaned up massive amounts of debris, and in a time period far shorter than anticipated, deconstructed and removed remains of buildings. Many had no training in response to civil disaster. The highly diverse nature of this workforce posed unprecedented challenges for worker protection and medical follow-up.

Workers were exposed to a complex mix of toxic chemicals and to extreme psychological trauma. These exposures varied over time and by location (Landrigan et al. 2004; Lioy et al. 2002). Combustion of 90,000 L of jet fuel immediately after the attacks created a dense plume of black smoke containing volatile organic compounds (including benzene), metals, and polycyclic aromatic hydrocarbons. The collapse of the twin towers (WTC 1 and WTC 2) and then of a third building (WTC 7) produced an enormous dust cloud containing thousands of tons of coarse and fine particulate matter (PM), cement dust, glass fibers, asbestos, lead, hydrochloric acid, polychlorinated biphenyls (PCBs), organochlorine pesticides, and polychlorinated dioxins and furans (Clark et al. 2003; Landrigan et al. 2004; Lioy et al. 2002; McGee et al. 2003). U.S. Environmental Protection Agency (EPA) estimates of airborne dust ranged from 1,000 to > 100,000  $\mu\text{g}/\text{m}^3$  (U.S. EPA 2002). The high

content of pulverized cement made the dust highly caustic (pH 10–11) (Landrigan et al. 2004; Lioy et al. 2002).

Dust and debris gradually settled, and rains on 14 September further diminished the intensity of outdoor ambient dust exposure. However, rubble-removal operations repeatedly re-aerosolized the dust, leading to continuing intermittent exposure for many months. Fires burned both above and below ground until December 2001 (Banauch et al. 2003; Chen and Thurston 2002; U.S. EPA 2003). Air levels of certain contaminants remained elevated well into 2002, with spikes in benzene and asbestos levels occurring as late as March and May 2002, respectively (U.S. EPA 2003).

Workers began noting symptoms soon after September 11, most commonly involving the aerodigestive tract (upper and lower respiratory tract and esophagus) (Banauch et al. 2006; Salzman et al. 2004; Szeinuk et al. 2003). New York City Fire Department (FDNY) firefighters experienced persistent cough, termed the “World Trade Center

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