PROTECTION OF ERGENCY RESPONDERS AGAINST DUST

Much attention has been given to protection of emergency responders and civilians against toxic chemicals including chemical warfare agents that might be released because of terrorist activities. But as the World Trade Center cleanup activities showed, emergency responders and cleanup workers need to be protected against the fine dust from pulverized buildings. Early testing by the Environmental Protection Agency following the terrorist attack of September 11, 2001 showed that the concentrations of asbestos, lead volatile organic compounds, and other selected toxic chemicals in the air at in lower Manhattan were below levels of concern, and some people assumed the air was safe for workers to breathe at the World Trade Center (WTC) site, but it was not.

The Dust at the World Trade Center Site

Above: Photographer Thomas E. Franklin captured firemen raising the flag at a dusty World Trade Center Site. This photo has been widely published and is available at http://www.arlingtoncemetery.net/fireman-01.htm.

On 7 September 2006, the Mount Sinai Medical Center released the findings from the World Trade Center Worker and Medical Screening Program. Of the approximately 40,000 firefighters, policemen, construction, and utility workers who worked at the site or were emergency responders, about 12,000 people participated in the study, and about 9,500 agreed to allow their results to be used in the report. Of the 12079 participants, 1660 were exposed to early high intensity dust exposure by being present during the collapse of the Towers. The screening included a comprehensive physical examination and other tests between July 2002 and April 2004. Another 4000 were tested after April 2004. The report concluded that (1) almost 70 percent of the responders had a new or worsened respiratory symptom that developed after or during their time working at the World Trade Center; (2) the responders had abnormalities in pulmonary function tests at the rate twice that expected in a comparable U.S. population, and that these abnormalities persisted for months and years; (3) 84 percent had upper respiratory illnesses; and (4) 47 percent has lower respiratory illnesses such as asthma. The findings are published in the Journal of the National Institute of Environmental Health Sciences.

CBS News has been following the effect of dust on responders, mostly from personal interviews. Information has been aired on 60 Minutes on 10 and 17 September 2006. The deaths of at four responders were attributed to inhaling the dust. One of them was 30-year-old New York City Police Det. James Zadroga who worked at ground zero for

several weeks. Shortly after that, he began getting sick. A scan of his lungs showed there were black rather than a healthy pink. His father recalled: "Every morning he would wake up and he said he would be coughing and hacking, and this black stuff would come up out of his lungs". One day his father did not hear him cough; "I saw him on the floor… I knew that he was gone". The coroner wrote on the autopsy report that the death was attributed to the dust inhaled at the WTC. Dr. David Prezant, the Chief Medical Officer for the New York City's Fire Department, who was caught in the dust cloud when the first tower fell, recalled: "The air was so thick that everything was stuck in your mouth, in your nose. You were pulling large pieces out, coughing like crazy. You could not inhale and swallowed tons of material" … "And then we went back down there the second and third day everyone was still coughing". [From http://www.cbsnews.com/stories/2006/09/07/60minutes/printable1982332.shtml.]

Little monitoring data is available during the first few days of the WTC attack when exposures were the greatest. After the first few days, site studies reported airborne particulates up to 100 mg/m^3 concentration. Settled dust samples were collected east of the site 5 and 6 days after the collapse. Most of the dust consisted of fine caustic cement particles which exhibited a pH of 9 to 11 when contacted with water. More than 90% of the particles in the bulk samples were greater than 10 microns (>10 μm) in diameter, and many were fibers with widths less than 5 μm and lengths greater than 10 μm. Also present were pyrolysis products (from fires, burning of jet fuel) and fines from mineral wool, fiberglass, gypsum, wood, glass, paper, cotton, and asbestos. Bronchoalveolar lavage (performed on one New York City firefighter hospitalized with pneumonitis several weeks after exposure) recovered considerable fly ash, degraded fibrous glass, and asbestos fibers along with evidence of significant inflammatory response. For further details on effects on New Your City firefighters see Environmental Health Perspectives, volume 112 No 15, Nov. 2004, pages 1564-1658. [Available from http.//www.ehponline.org/members/2004/7233/7233.pdf.]

Dr Frederick Miller, an inhalation dosimetry expert at CIIT Centers for Health Research, commented that it is the smallest particulates that are the most dangerous. The relatively smaller particles can be breathed and lodged in the tracheobronchial area and cause lasting irritation, even though most will be cleared from the lungs in about 24 hours. These particles are alkaline and contribute to "fireman's cough" experienced by responders. The very smallest particles lodge deep into the alveolar spaces of the lungs and takes months to clear. [The CBS 60 minute report cited above questioned whether some of the responders will ever recover]. Other studies indicated that the very smallest particulates (about 20 nanometers in size) can become translocated from the lungs to the liver and brain.

Dr. John R. Balmes, MD, at the University of California, San Francisco Lung Biology Center, commented (in August 2006 issue of the American Journal of Respiratory and Critical Care Medicine) on the value of medical surveillance for workers in jobs with high risk for inhalation exposure to toxicants. Virtually all the New York City firefighters had baseline pulmonary function tests prior to the WTC incident. But Dr.

Balmes added that this occupational problem could have been prevented with "early and well-trained use of simple respiratory protection equipment".

Adequate respiratory protection was almost nonexistent among responders during the first few days following the WTT attack. Insufficient respirators were available, and masks became quickly clogged with dust. Within a few weeks of the attack, the Centers for Disease Control and the NYC Fire Department sent out a questionnaire to a random sample of 319 firefighters responding to the World Trade Center Site inquiring on their use of respirators. Of the 149 firefighters present during the collapse, 52% wore no respiratory protection, and of the remainder firefighters who arrived later, 38% wore no respiratory protection. Of those who did wear some kind of respiratory protection, most used the disposable mask (like the kind sold in hardware and paint stores) during the first day. During the initial 2-week period, use of half-face respirators increased and use of disposable masks decreased. (Information from Centers for Disease Control, MMWR 51:6-8, issued Sept. 11, 2002, available at http://www.cdc.gov/mmwr/preview/mmwrhtml/mm55Spa2.htm.)

Video clips aired recently on television taken inside the remaining tower after collapse of the first tower showed a very dusty atmosphere which a person could barely see even with portable lights, and many of the responders were even unaware of what was taking place. The effort was on getting as many people out safely. After the collapse of both towers, the effort by firefighters was on searching for people who may be trapped in the dust rubble and not on personal safety.

Respirator Selection

U.S. governmental agencies have issued rules for selection and use of respirators. Two major agencies involved in rule making are the National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA). The two agencies work closely together on this. We will discuss generally what is involved in respirator selection by responders and then consider the specific protection against inhaling particulate dust.

NIOSH has issued a respirator selection logic sequence (see NIOSH Publication No. 2005-100, available at http://www.cdc.gov/niosh/docs/2005-100/chapter3.html; also OSHA General Industry Air Contaminants Standard in 29 CFR 1910.1000). NIOSH starts out by saying, "After all criteria have been identified and evaluated and after the requirements and restrictions of the respiratory protection program have been met, the following sequence can be used to identify the class of respirators that should provide adequate respiratory protection". [*Obviously, these criteria could not be applied during the rapidly changing circumstances of the 11 September 2001 attack; the emphasis by responders was on trying to get as many people out of the towers and away from the area as they could, and the responders themselves did not know what was happening. It is presented here as a starting point for respiratory protection.*]

The essentials of NIOSH logic sequence is listed below. Full text is at http://www.cdc.gov/niosh/docs/2005-100/chapter3.html.

Step 1: Is the respirator intended for use during firefighting? If "yes" only a full-facepiece, pressure demand Self-Contained Breathing Apparatus (SCBA) meeting the requirement of NFPA 1981 (see http://www.nfpa.org) is required. If "no" proceed to step 2.

Step 2: Will the respirator be used in an oxygen-deficient atmosphere (<19.5% oxygen)? If "yes", any type of SCBA other than escape only, or supplied-air respirator with an auxiliary SCBA is required. Auxiliary SCBA must be of sufficient duration to permit escape to safety if the air supply is interrupted.

Step 3: Is the respirator intended for entry into an unknown or concentrations above Immediately Danderous to Life and Health (IDLH)? If "yes" either a pressure-demand SCBA with a full facepiece or a pressure-demand supplied-air respirator with a full facepiece in combination with an auxiliary pressure demand SCBA is required. Auxiliary SCBA must be of sufficient duration to permit escape to safety if the air supply is interrupted. If "no" proceed to step 4.

[*Comment: Most air purifying respirators will protect above IDLH concentrations; the concern is that in case of air purifying respirator failure that the person will be able to escape in 30 minutes.*]

Step 4. Is the contaminant an eye irritant or can cause eye damage at the exposure concentration? If "yes", a respirator with a full facepiece, helmet, or hood is recommended. If "no", a half-mask or quarter-mask respirator may be an option depending upon the chemical and ambient concentration. Proceed to step 5.

Step 5. If the contaminant is a particulate (solid or liquid aerosol), proceed to step 6. If the contaminant is a gas or vapor, proceed to step 7. If the contaminant is a combination of a gas or vapor and particulate or if unsure, proceed to step 8. For organic pesticides that appears to be in the form of a dust, proceed to step 8.

Step 6. **Particulate Respirators.** The user has a choice of using filters in the N-, R-, or P- series, and selection of various filter efficiencies of up to 99.97% efficiency. *[The P-Series is what is recommended for Chemical, Biological, Radiological, or Nuclear (CBRN) events. For CBRN events, use a P-series filter rated at 99.97% efficiency. N-series filters cannot be used if oil particles are present as an aerosol, and a R- series filter should not be used for more than one work shift if oil particles are present. The P-series does not have these restrictions.]*

NIOSH-certified P100 filters are rated at a 99.97% removal efficiency and have at least a 200 mg particulate loading.

[*Comment: 99.97% removal efficiency for P100 cartridge filters is defined in terms of an OSHA/NIOSH test where the cartridge must remove at least 99.97% of monodispersed particles 0.3 micrometers in diameter, see NIOSH website, http://www.cdc.gov/niosh/respguid.html for details.*]

NIOSH has issued rules (table 1) on the type of respirators allowed for various assigned protection factors. The protection factor is the ratio of the assault (ambient) particulate concentration to the concentration inside the mask. The assumption is made that the respirator user adheres to complete program requirements (29CFR1910.134) including individual fit testing.

Table 1. Particulate Respirators

Assigned protection factor	Type of Respirator
5	Quarter mask respirator
10	Any air-purifying elastomeric half-mask respirator equipped with appropriate type of particulate filter. Appropriate filtering facepiece respirator. Any air-purifying full facepiece respirator equipped with appropriate type of particulate filter. Any negative pressure (demand) supplied-air respirator equipped with a half-mask.
25	Any powered air-purifying respirator equipped with a hood or helmet and a high efficiency (HEPA) filter. Any continuous flow supplied-air respirator equipped with a hood or helmet.
50	Any air-purifying full facepiece respirator equipped with N-100, R-100, or P-100 filter(s). Any powered air-purifying respirator equipped with a tight-fitting facepiece (half or full facepiece) and a high-efficiency filter. Any negative pressure (demand) supplied-air respirator equipped with a full facepiece. Any continuous flow supplied-air respirator equipped with a tight-fitting facepiece (half or full facepiece). Any negative pressure (demand) self-contained respirator equipped with a full facepiece.
1,000	Any pressure-demand supplied-air respirator equipped with a half-mask.
2,000	Any pressure-demand supplied-air respirator equipped with a full facepiece.
10,000	Any pressure-demand self-contained respirator equipped with a full facepiece. Any pressure-demand supplied-air respirator equipped with a full facepiece in combination with an auxiliary pressure-demand self-contained breathing apparatus.

Step 7. Gas/Vapor Respirators. The user may select any air-purifying chemical cartridge or canister that has a sorbent suitable for removing the contaminant.

NIOSH has issued rules (table 2) on the type of respirators allowed for various assigned protection factors. The protection factor is the ratio of the assault (ambient) particulate concentration to the concentration inside the mask. The assumption is made that the respirator user adheres to complete program requirements (29CFR1910.134) including individual fit testing.

Table 2. Gas/Vapor Respirators

Assigned protection factor	Type of Respirator
10	Any air-purifying half mask respirator equipped with appropriate gas/vapor cartridges. Any negative pressure (demand) supplied-air respirator equipped with a half mask.
25	Any powered air-purifying respirator with a loose-fitting hood or helmet equipped with appropriate gas/vapor cartridges. Any continuous flow supplied-air respirator equipped with a hood or helmet.
50	Any air-purifying full facepiece respirator equipped with appropriate gas/vapor cartridges or gas mask (canister respirator).[2] Any powered air-purifying respirator equipped with a tight-fitting facepiece (half or full facepiece) and appropriate gas/vapor cartridges or canisters. Any negative pressure (demand) supplied-air respirator equipped with a full facepiece. Any continuous flow supplied-air respirator equipped with a tight-fitting facepiece (half or full facepiece). Any negative pressure (demand) self-contained respirator equipped with a full facepiece.
1,000	Any pressure-demand supplied-air respirator equipped with a half-mask.
2,000	Any pressure-demand supplied-air respirator equipped with a full facepiece.
10,000	Any pressure-demand self-contained respirator equipped with a full facepiece. Any pressure-demand supplied-air respirator equipped with a full facepiece in combination with an auxiliary pressure-demand self-contained breathing apparatus.

Step 8. Combination Particulate and Gas/Vapor Respirators.
These respirators have both a particulate filter and a gas/vapor cartridge combination. The user may also use a separate P100 filter cartridge in combination with an appropriate gas vapor cartridge.

NIOSH has issued rules (table 3) on the type of respirators allowed for various assigned protection factors. The protection factor is the ratio of the assault (ambient) particulate concentration to the concentration inside the mask. The assumption is made that the respirator user adheres to complete program requirements (29CFR1910.134) including individual fit testing.

Table 3. Combination Particulate and Gas/Vapor Respirators

Assigned protection factor	Type of Respirator
10	Any air-purifying half-mask respirator equipped with appropriate gas/vapor cartridges in combination with appropriate type of particulate filter. Any full facepiece respirator with appropriate gas/vapor cartridges[2] in combination with appropriate type of particulate filter. Any negative pressure (demand) supplied-air respirator equipped with a half-mask.
25	Any powered air-purifying respirator with a loose-fitting hood or helmet that is equipped with an appropriate gas/vapor cartridge2 in combination with a high-efficiency particulate filter . Any continuous flow supplied-air respirator equipped with a hood or helmet.
50	Any air-purifying full facepiece respirator equipped with appropriate gas/vapor cartridges[2] in combination with an N-100, R-100 or P-100 filter or an appropriate canister[2] incorporating an N-100, P-100 or R-100 filter. Any powered air-purifying respirator with a tight-fitting facepiece (half or full facepiece) equipped with appropriate gas/vapor cartridges in combination with a high-efficiency filter or an appropriate canister incorporating a high-efficiency filter. Any negative pressure (demand) supplied-air respirator equipped with a full facepiece. Any continuous flow supplied-air respirator equipped with a tight-fitting facepiece (half or full facepiece). Any negative pressure (demand) self-contained respirator equipped with a full facepiece.
1,000	Any pressure-demand supplied-air respirator equipped with a half-mask.
2,000	Any pressure-demand supplied-air respirator equipped with a full facepiece.
10,000	Any pressure-demand self-contained respirator equipped with a full facepiece. Any pressure-demand supplied-air respirator equipped with a full facepiece in combination with an auxiliary pressure-demand self-contained breathing apparatus.

Lists of NIOSH-Approved Respirators

A list of NIOSH-certified particulate respirators in all classes is at the website,

http://www2a.cdc.gov/drds/cel/cel_results.asp?startrecord=1&maxrecords=50&schedule=21C&aptype_2=ON&appdatefrom=&appdateto=&powered=&scbatype=&scbause=&privatelabel .

[D*on't forget when visiting this website that there are several pages to the list and only the first page appears.*]

For CBRN events, use a P-series filter rated at least 99.97% efficiency.

Particulates include viruses and other biological materials. Respirators providing biological protection are listed at
http://www.cdc.gov/niosh/npptl/topics/respirators/disp_part/ .

Combination NIOSH-approved gas/vapor air purifying respirators for CBRN use are listed at
http://www.cdc.gov/niosh/npptl/topics/respirators/cbrnapproved/apr/default.html#list .

NIOSH-approved SCBA respirators for CBRN use are listed at
http://www.cdc.gov/niosh/npptl/topics/respirators/cbrnapproved/scba/ .

For a generalized selection guide of NIOSH-approved respirators (not just CBRN use) visit http://www2a.cdc.gov/drds/cel/cel_form_code.asp .

These websites also contain links on how the respirators become NIOSH certified.

What Respiratory Protection is Needed?

Each situation is different. Emergency response personnel must be trained in the use of personal protection equipment. Appropriate equipment must be available to handle situations which may potentially arise.

The rapidly-changing circumstances during the 9-11 attack demonstrated that even with excellent training responders are overwhelmed. Pulverized building dust is a major concern following the collapse of large buildings. Terrorist attacks are not the only cause of building collapse. Buildings and other structures may collapse during a major earthquake. This is another overwhelming event for responders.

The major inhalation hazard was from breathing dust at the World Trade Center site. The dust was from the pulverized buildings; it was mostly alkaline concrete fines, gypsum, fiberglass, some asbestos or asbestos-like particles (fine needle-like material which was easily wedged in the respiratory track) and not something unusual like a toxic chemical or radioactive isotopes from a dirty bomb. Some toxic chemicals such as polycyclic hydrocarbons and dioxins likely were present in minute amounts (any building fire will produce these toxic chemicals). A half-face respirator with a good particulate removal

cartridge would definitely help. Face masks using a paint filter would be inadequate against protection from the fines.

But even a NIOSH-certified P100 filter rated at 200 mg loading would probable be inadequate just after collapse of the first tower for firemen escaping the second tower and nearby. The dust was reported to be so dense that a person could barely see even with lights. Any air-purifying respirator would become quickly clogged. No measurements of the dust concentration in the air were taken, but assuming a 2 gram/m^3 ambient concentration and a fireman breathing at 50 liters per minute, one filter cartridge would last only 2 minutes. After the first few days, ambient concentrations of up to 100 mg/m^3 were measured at the site, and a 99.97% removal filter cartridge rated at 200 mg loading would provide good service.

NIOSH-certified P100 filter cartridges also provide good respiratory protection against radioactive isotopes dispersed from a dirty bomb or from radioactive fallout from a nuclear event. Even with suiting and with shower and change out facilities and respirator protection, responders will experience some radiation exposure. But the big danger occurs if any radioactive isotopes are inhaled along with the dust. The radioactive isotopes are now inside the body and cannot be washed away.

Again, appropriate equipment must be on hand for emergency responders, and they must be trained as to its use.

Additional Reading

See June 2004 (issue 26) of The First Responder, "NIOSH Certification of Personal Protective Equipment for CBRN"
http://www.aristatek.com/Newsletter/04%2006%20June/The%20First%20Responder%20Technically%20Speaking.htm.