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PROTECTING EMERGENCY RESPONDERS

VOLUME 4

Personal Protective Equipment Guidelines for Structural Collapse Events

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Prepared for the
National Institute for Occupational Safety and Health

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Summary

At the request of the National Institute for Occupational Safety and Health (NIOSH), the RAND Corporation undertook research and analyses to develop guidelines for personal protective equipment (PPE) for emergency responders to a large structural collapse. This work is motivated by the experiences of responders from the terrorist attacks on the Pentagon, the World Trade Center (WTC), and the Murrah Federal Building in Oklahoma City.

The primary purpose of this monograph is to serve as a technical source for incident commander guidelines that have been developed by NIOSH for broad distribution to the disaster management and emergency responder communities.

Scope and Approach

In this monograph, we characterize response activities and expected hazards, and develop guidelines for PPE following the collapse of a multistory commercial or residential building. We focus on the first days of response, because it is during this time that the hazards, uncertainty, response intensity, and logistical challenges are greatest. Precautions and PPE intended for chemical, biological, radiological, or nuclear attacks are not within the scope of our investigation.

During the first days following the collapse of a multistory building, responders and response managers rely on information that is readily available, such as visual cues or knowledge of the building's structural materials, contents, and occupants. The guidelines in this monograph translate this information into actionable steps responders can take in selecting, using, and maintaining PPE.

Hazards of Structural Collapse

The partial or complete collapse of a multistory building creates an array of physical, chemical, and biological hazards. The specific hazards present depend on the cause of the collapse (e.g., structural failure, earthquake, explosion), the magnitude of the

failure (i.e., size of the building and completeness of the collapse), building materials and contents, the use and on-site storage of chemicals, the presence and duration of fires, and weather conditions during and immediately following the collapse.

These factors combine to create an environment containing multiple hazards. Physical hazards, from electrical equipment, noise, vehicles and heavy equipment, sharp objects, falling objects, and uneven or unsteady working surfaces, are a major cause of injuries and fatalities at building collapses. Chemical hazards can be created by fires and pulverization of building materials and contents. Biological hazards may exist, but situations in which they are substantial are easily characterized. Bloodborne pathogens, such as human immunodeficiency virus (HIV), the hepatitis B virus, and the hepatitis C virus, present risks only in the event of direct contact with infected bodily fluids. Such contact would occur only when responders are treating victims or handling human remains. Serious health consequences from other infectious diseases or waterborne pathogens are less likely and more easily managed. Significant sources of such hazards—pooled sewage, for instance—are easily identifiable.

Guidelines for PPE Ensembles at Multistory-Building Collapse Events

The guidelines focus on three issues that present unique challenges in the response to a multistory-building collapse: (1) protection from biological hazards; (2) protection from inhalation of hazardous materials; and (3) required modifications to responders' typical ensembles.

PPE Required for Protection from Biological Hazards

Biological hazards consist, primarily, of bloodborne and waterborne pathogens. Although potentially dangerous, detecting such hazards and protecting responders from them is straightforward.

Protection from Bloodborne Pathogens. Responders equipped with National Fire Protection Association (NFPA)–approved PPE generally do not require additional protection from bloodborne pathogens. Responders who are actively treating victims or working with human remains, however, must take extra precautions. These precautions include using gloves that provide resistance to viral pathogens (e.g., latex or nitrile gloves) and goggles or a faceshield to limit exposure to splashes of blood to the eyes, nose, and mouth. Since gloves designed to prevent the transmission of viruses are typically prone to puncture and tear, they must be used as undergloves (or replaced with more durable gloves) when moving through or handling rubble and debris.

Protection from Waterborne Pathogens. Infection from waterborne pathogens is only a concern if the pathogens are able to enter the body through cuts in the skin or contact with mucous membranes (i.e., the eyes, nose, or mouth). Exposures would result from contact with pools of sewage or contaminated water or from contact with waterborne pathogens in the dust at the collapse site. To protect against exposure from pools of sewage or contaminated water, water-resistant clothing and boots must be worn. When such equipment is not used, emergency responders must promptly remove contaminated equipment, wash exposed areas with soap and water, and acquire replacement or decontaminated PPE before resuming work. For protection from pathogens in dust, responders require a skin barrier that minimizes contact with the dust and provides protection from cuts, scrapes, and punctures.

PPE Required for Protection from Inhalation of Hazardous Materials

Environmental monitoring must be initiated as soon as possible. Obtaining complete and accurate information about the kind and level of chemical hazards that might be present in the air immediately following the collapse of a multistory building, however, will be difficult, if not impossible. Monitoring equipment will not be readily available, and other needs will be too pressing. Before data from direct monitoring are available, incident command must make on-the-spot decisions about what PPE must be worn to guard against present hazards. The use of visual cues and knowledge of building characteristics can aid this decisionmaking process.

If any of the following factors are present, all emergency responders in the area must wear respiratory protection: low oxygen levels, smoke from active and smoldering fires, irritant dusts (e.g., from concrete, glass, or other building materials), or chemical hazards (e.g., from silica, asbestos, metals, or organic compounds).

Protection in Oxygen-Deficient Environments. A supplied-air breathing apparatus, such as a self-contained breathing apparatus (SCBA), must be used in oxygen-deficient environments. If low-oxygen conditions are suspected or work is to be conducted in a confined space, oxygen levels in the air must be monitored. This can be done using the four-gas monitors typically used by firefighting companies.

Respiratory Protection Around Fires. When working around active fires, emergency responders should wear an SCBA for protection from carbon monoxide, organic compounds, and other hazardous byproducts of combustion. When working around fires is mission-critical, and supplied air respirators are either unavailable or their use is incompatible with the mission at hand, responders must use an air-purifying respirator (APR) and the work environment should be continuously monitored for oxygen and carbon monoxide levels.

A full-facepiece APR or powered air-purifying respirator (PAPR) with combined particulate, organic vapor, and acid gas cartridges may provide acceptable protection against the organic vapors and toxic gases present in smoke. However, APRs must not be worn for work in oxygen-deficient environments, as discussed previously, or in atmopheres that are immediately dangerous to life and health (IDLH), because failure of the mask or chemical cartridge would place a responder's life at risk. Incident commanders should be aware that, when exposure-monitoring data are not available, use of an APR can place responders at risk of hazardous exposure.

Respiratory Protection from Particulate Matter. When response activities require entry into areas where the visibility is less than 30 feet, responders must wear an SCBA. Half-mask APRs, full-facepiece APRs, and PAPRs are not appropriate at these high-particulate concentrations, because they will clog rapidly and will not provide adequate protection if responders encounter oxygen-deficient atmospheres or IDLH concentrations. Given the irritant nature of these dusts, individuals lacking respiratory protection who are exposed to these concentrations of dusts must be immediately removed from the site and provided with medical attention.

Even after the initial dust cloud has settled, work at the collapse site can resuspend hazardous quantities of dust. When visibility is greater than 30 feet and smoke plumes from active or smoldering fires are not present, visibility estimates suggest total dust concentrations will be less than 150 milligrams per cubic meter (mg/m^3). Under these conditions, either a PAPR or a full-facepiece APR with a combination particulate, organic vapor, and acid gas cartridge must be worn to provide adequate protection from dust. In high-dust conditions, a fabric prefilter must be used to prevent clogging of the cartridge. If eye protection is unnecessary or provided by goggles, a half-mask APR with the cartridge described previously and prefilter can be worn to provide adequate levels of protection. However, half-mask APRs will allow hazardous exposures when chemicals are present at concentrations above the calculated maximum-use concentration.

Given the large amount of dust generated at the WTC and Oklahoma City collapses, it is reasonable to expect that all responders to large structural collapse, even those serving in support roles, will need some respiratory protection. Thus, all responders should have access to at least half-mask APRs with combined particulate, organic vapor, and acid gas cartridges.

Protection from Chemical Hazards. Even when responders are protected from dusts and total particulates in the air, they may be exposed to hazardous chemicals that are constituents of these dusts. Asbestos and crystalline silica are of particular concern because of their toxicity and prevalence in building materials.

Monitoring data are required to select appropriate respirators properly. Without monitoring data, uncertainties in the magnitude and composition of respiratory exposures at a multistory-building collapse dictate that only SCBAs can ensure that responders are not exposed to hazardous chemicals at levels above NIOSH recommended exposure limits (RELs) or Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs). However, SCBAs are heavy and cumbersome, so using them can limit responders' abilities to engage in critical lifesaving tasks and may place them at even greater risk of immediate injury or death.

Using either PAPRs or APRs significantly decreases responder exposures. PAPRs provide several benefits over both APRs and SCBAs. Because PAPRs provide a constant supply of air at positive pressure using a battery-powered motor, they are not subject to the same fit testing requirements, mask fogging difficulties, and breathing hindrances that APRs present. In addition, they are lighter and less cumbersome than SCBAs. On the other hand, PAPRs are more expensive than APRs, require an adequate supply of recharged batteries, and consume more cartridge filters because air is constantly passed through them at a high rate.

Nevertheless, both PAPRs and APRs place responders at some level of marginal risk for the few days that they are responding at the collapse site. Although current knowledge of the chronic effects of short-term exposures does not provide a basis for quantifying this risk, it does suggest that these short-duration exposures present lower risks than lifetime exposures. In choosing between SCBAs, PAPRs, and APRs when exposure monitoring and assessment is not available, incident commanders must balance the increased burdens SCBAs present on lifesaving missions, risks SCBAs present for responders, and risks responders may face while using PAPRs and APRs.

PPE Ensemble Modifications

Immediately following a structural collapse, law enforcement, capable victims of the collapse, and witnesses near the incident generally become part of a spontaneous emergency response. None of these individuals will have the respiratory, head, eye, or skin protection against the hazards expected at a multistory-building collapse. Thus, all those involved in the immediate aftermath of the building collapse will require medical evaluation, and possibly medical attention and screening.

During the organized response, hazards from a multistory-building collapse will likely require additions or modifications to responders' standard PPE ensembles.

Urban Search and Rescue Ensembles. The urban search and rescue (USAR) ensemble, as specified in NFPA 1951 (NFPA, 2001a), is the most appropriate PPE ensemble for response to a multistory-building collapse. The exception occurs when fires or high temperatures are present, in which case a structural firefighting ensemble (NFPA 1971) (NFPA, 2000a) is required. Otherwise, the standard USAR ensemble requires three modifications needed to address the environment and hazards at a large structural collapse.

Additional Biological Protection. The USAR ensemble components are rated to provide an impermeable barrier from bloodborne pathogens; this barrier is only adequate so long as the gloves and their seams are intact. When exposure to bloodborne pathogens is more likely, USAR teams must wear further protection from biological hazards, such as latex or nitrile gloves and a faceshield.

Additional Respiratory Protection. USAR teams typically have access to no more than half-mask APRs. For work in the hot and warm zones, greater respiratory protection will likely be needed. USAR teams will need access to full-facepiece APRs, PAPRs, or SCBAs as necessary.

Excessively Heavy Helmets. The NFPA 1951 helmet standards currently provide more protection for heat than is needed when fires are not present. This additional thermal resistance makes the helmets heavy. In the absence of extreme heat conditions, the lighter NFPA 1977 (NFPA, 2005a) helmets are recommended.

Firefighter Ensembles. The ensemble for structural firefighting, as outlined in NFPA 1971, protects responders from severe hazards while they are working around active fires and intense heat. When fires are present, the NFPA 1971 ensemble must be worn. The greatest deficiency of the NFPA 1971 ensemble for response to a multistory-building collapse is that the heat protection incorporated into the NFPA 1971 makes its garments, gloves, and helmet heavy, cumbersome, and, depending on the weather, excessively warm. Wearing this ensemble places responders at risk of injury from falls or exhaustion. Thus, the NFPA 1971 ensemble should not be worn when excessive heat from fires is not a hazard.

In the absence of active fires, firefighters should wear the modified USAR ensemble discussed previously, which incorporates biological protection as necessary. Firefighters should also have access to respiratory protection other than SCBAs, such as full-facepiece APRs or PAPRs, and should be provided fit testing and training required for this equipment.

Emergency Medical Services Ensembles. The standard emergency medical services (EMS) PPE ensemble (NFPA 1999) (NFPA, 1992) is not intended to provide protection from many of the physical and chemical hazards expected from a multistory-building collapse. EMS personnel should wear clothing, gloves, footwear, and head protection equivalent to that worn by the USAR teams. Since EMS staff will most likely be treating victims, gloves and face protection from bloodborne hazards are still necessary. Finally, as with other emergency responders at the collapse site, EMS personnel must wear respiratory protection consistent with the standards specified previously.

Law Enforcement Ensembles. The primary roles of law enforcement during the initial hours and days of the response are to control the event perimeter and to investigate the site as a crime scene. For perimeter control, law enforcement responders should be removed from the physical and chemical hazards at the collapse unless assistance in access control is required in areas adjacent to those directly affected by the collapse event.

Additional PPE is necessary if law enforcement responders must enter areas of intense effort or support these efforts. In this event, law enforcement responders need head, eye, body, foot, hand, and respiratory equipment equivalent to the modified USAR ensemble discussed previously. Even if not entering these areas, all law enforcement officials will need viral penetration–resistant (e.g., latex or nitrile) gloves and eye and face protection if they are expected to assist in treating victims from the collapse.

PPE for Other Responders. If individuals from construction and trade industries, utility company personnel, or volunteers must work in and around the response effort, they must wear the modified USAR ensemble discussed previously along with all relevant occupation-specific PPE, such as eye protection for welders and insulating gloves for electrical workers. Since many of these individuals will not have access to the required PPE, emergency response planners must plan for the training and equipment supply necessary to protect these groups of responders.

Ensuring Availability and Appropriate Use of PPE

Selecting and purchasing appropriate PPE does not ensure safety; the equipment must also be readily available and must be used correctly. Thus, all emergency responders need to know where to get equipment, how to don it, what maintenance is required during use, when and how to clean or replace the PPE, and any limitations of the protective performance of the equipment.

Supply and Logistics

The typical PPE ensemble for some emergency responders will not be appropriate for use at a multistory-building collapse site. Also, additional equipment will be needed to replace and dispose of contaminated, damaged, or exhausted PPE. To address PPE supply and distribution problems, disaster management plans for metropolitan areas with multistory buildings should include logistical measures to disseminate rapidly and to maintain required PPE.

Integration and Compatibility

Incompatibilities between PPE components can compromise both the performance of the PPE and a responder's ability to work or maneuver. Thus, equipment must be tested to see how well various PPE components function together.

Training

Many responders at a multistory-building collapse will be using some types of PPE for the first time. Without proper training, responders can place themselves or others in harm's way. Since OSHA mandates training for the use of most PPE, especially respiratory protection, consideration must be given to either (1) how required training will be provided during disaster response or (2) how responders without proper training will be reassigned to appropriate tasks.

Decontamination

Decontamination of PPE and all body surfaces (e.g., skin and hair) must be conducted before any responder leaves the collapse site. The two primary sources of contamination in a post-structural collapse environment are (1) dust from fires and structural collapse, and (2) bloodborne pathogens from victims and human remains. Decontamination is required to ensure that emergency responders do not carry contamination with them off the site and, in doing so, endanger themselves and those around them.

Remaining Challenges for Protecting Emergency Responders at Multistory-Building Collapse Events

The most significant uncertainties are the composition and magnitude of the hazards present in the postcollapse environment. Although this uncertainty is reducible through hazard monitoring, this type of monitoring will not be available during the first few hours after a building collapse. Two areas that require further examination are the (1) logistical and practical demands of putting these protective guidelines into practice and (2) the uncertainties associated with the effects of infrequent, short-duration, multiple-chemical, high-magnitude exposures. These issues can only be addressed with investments in research to build a stronger understanding of the response community, technologies to improve PPE, and the health effects of hazardous exposures.