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**Guidance for Respiratory and Ventilation Protection
against Airborne Weapons of Mass Destruction**

Mark D. Hoover and Herman Cember

Chapter 24 from

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Chemical, and Biological Terrorism***

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Chapter 24

Guidance for Respiratory and Ventilation Protection Against Airborne Weapons of Mass Destruction

Mark D. Hoover and Herman Cember

Introduction

Gas attacks in Tokyo, the Oklahoma City bombing, the World Trade Center and Pentagon attacks, and anthrax letter attacks; these tragic events have illustrated the realities of threats we face and the urgency to understand and prepare for future anticipated or unanticipated types of attack. This chapter summarizes guidance for respiratory and ventilation protection against airborne weapons of mass destruction (WMD) involving chemical, biological, and radiological (CBR) agents. General aerosol science considerations for respiratory and ventilation protection are provided in Chapter 23 (Cember and Hoover 2004).

Protecting Building Environments

In January 2002, the White House Office of Homeland Security (predecessor to the U.S. Department of Homeland Security [DHS]) formed an Interagency Workgroup on Building Air Protection under its Medical and Public Health Preparedness Policy Coordinating Committee. Noting that prevention is the cornerstone of public and occupational health, the National Institute for Occupational Safety and Health (NIOSH), which is part of the Centers for Disease Control and Prevention (CDC) in the U.S. Department of Health and Human Services, issued a guidance document (NIOSH 2002) summarizing key findings of building vulnerability assessments conducted by NIOSH, along with significant content and review recommendations provided by Workgroup members. The document also provided contact information and general descriptions for a number of other organizations that have guidance addressing security needs and disaster response plans for events such as fire, natural disasters, and bomb threats. (See Appendix A.12 for an expanded list of these organizations.)

The NIOSH guidance on preventive measures that building owners and managers can implement promptly to protect building air environments from terrorist release of CBR contaminants was intended to serve as a source of timely and feasible guidance to enable building owners to implement some level of protection while NIOSH and others produced more comprehensive guidance. It was noted that the likelihood of a specific building being targeted for terrorist activity is generally difficult to predict; that no specific formula will determine a building's level of risk; and that no building can be fully protected from a determined individual who is intent on releasing a CBR agent. Key considerations and recommendations of the NIOSH guidance are summarized in the following sections. Additional NIOSH guidance for filtration and air-cleaning systems to protect building

environments from airborne chemical, biological, or radiological attacks can be found in a companion document (NIOSH 2003a).

Preparatory Recommendation: Know Your Building

The NIOSH document notes that an important first step is to understand how the building ventilation system is intended to operate and how it is currently operating. Questions to be considered include, but are not limited to:

1. What is the mechanical condition of the equipment?
2. What filtration systems are in place?
3. What are their efficiencies?
4. Is all equipment appropriately connected and controlled?
5. Are equipment access doors and panels in place and appropriately sealed?
6. Are all dampers (outdoor air, return air, bypass, fire and smoke) functioning?
7. How well do they seal when closed?
8. How does the heating, ventilating, and air conditioning (HVAC) system respond to manual fire alarm, fire detection, or fire-suppression device activation?
9. Are all supply and return ducts completely connected to their grilles and registers?
10. Are the variable air volume (VAV) boxes functioning?
11. How is the HVAC system controlled?
12. How quickly does it respond?
13. How is the building zoned?
14. Where are the air handlers for each zone?
15. Is the system designed for smoke control?
16. How does air flow through the building?
17. What are the pressure relationships between zones?
18. Which building entryways are positively or negatively pressurized?
19. Is the building connected to other buildings by tunnels or passageways?
20. Are utility chases and penetrations, elevator shafts, and fire stairs significant airflow pathways?
21. Is there obvious air infiltration?
22. Is it localized?
23. Does the system provide adequate ventilation given the building's current occupancy and functions?
24. Where are the outdoor air louvers?
25. Are they easily observable?
26. Are they or other mechanical equipment accessible to the public?
27. Do adjacent structures or landscaping allow access to the building roof?

If sufficient questions or surprises arise from this process, an independent evaluation by a qualified HVAC professional should be used to establish a useful baseline.

Specific Things Not to Do

More than anything else, building owners and managers should ensure that their actions do not have detrimental effects on normal building operation. Things not to do include:

1. *Do not permanently seal outdoor air intakes.* Buildings require a steady supply of outdoor air during normal building operations to maintain environmental quality appropriate to their occupancy and function.
2. *Do not modify the HVAC system without first understanding the effects on the building systems or the occupants.* If there is uncertainty about the effects of a proposed modification, a qualified professional should be consulted.
3. *Do not interfere with fire protection and life safety systems.* Such systems should not be altered without guidance from a specifically qualified professional.

Physical Security

Specific physical security measures for each building should be based on vulnerabilities of the facilities and anticipated threats. (Measures considered to be highly critical are identified by “****” next to the recommendation.) The following physical security actions are applicable to many building types:

1. *Prevent access to outdoor air intakes.****
Do not enable a terrorist to use the HVAC system as a means of dispersing a CBR agent throughout a building. Relocate accessible air intakes, especially those at or below ground level, to publicly inaccessible locations such as a secure roof or a high sidewall that is away from any retaining walls, loading docks, or handrails that might provide access. If relocation of outdoor air intakes is not feasible, construct intake extensions that do not adversely affect HVAC performance. Additional details are provided in the NIOSH report, including guidelines for covering air intakes with a sloped metal mesh to reduce the threat of objects being tossed into the intake. A minimum slope of 45° is generally adequate. If relocation or physical extensions are not viable options, consider security perimeter barriers to prevent public access. Use iron fencing or similar see-through barriers that will not obscure visual detection of terrorist activities or a deposited CBR source. Include an open buffer zone between the public areas and the intake louvers to make individuals attempting to enter these protected areas more conspicuous to security personnel and the public. Monitoring the buffer zone by physical security, closed circuit television, security lighting, or intrusion detection sensors will enhance this protective approach.

2. *Prevent public access to mechanical areas.****
Control access to mechanical areas by keyed locks, keycards, or similar security measures to prevent centralized HVAC, elevator, water, or other systems from being tampered with or subsequently used in a CBR attack.
3. *Prevent public access to building roofs.****
From a physical security perspective, roofs are like other entrances to the building and should be secured appropriately. Fencing or other barriers should restrict access from adjacent roofs. Roofs with HVAC equipment should be treated like mechanical areas. Fire and life safety egress should be carefully reviewed when restricting roof access.
4. *Implement security measures, such as guards, alarms, and cameras to protect vulnerable areas.*
Difficult-to-reach outdoor air intakes and mechanical rooms alone may not stop a sufficiently determined person. Additional measures may be needed to deter security breaches.
5. *Physically isolate lobbies, mailrooms, loading docks, and storage areas from the rest of the building.*
Areas where bulk quantities of CBR agents are likely to enter a building should be protected or isolated by security checks of individuals and packages prior to their entry, isolated HVAC systems, well-sealed floor to roof-deck walls, sealed wall penetrations, and negative pressure relative to the rest of the building. Some measures are more feasible for new construction or buildings undergoing major renovation. A qualified HVAC professional can assist in determining whether isolation is feasible for a given building. Side entry doors that circumvent established security checkpoints should be strictly controlled. Building doors, including vestibule and loading dock doors, should remain closed when not in use.
6. *Secure return air grilles.*
Treat return air grilles similar to the outdoor-air intakes by (1) relocating return-air grilles to inaccessible, yet observable, locations, (2) increasing human or electronic observation of vulnerable return-air grilles, (3) directing public access away from return-air grilles, and (4) removing furniture and visual obstructions from areas near return-air grilles. Take care not to adversely affect the performance of the building HVAC system.
7. *Restrict access to building operation systems by outside personnel.*
Deter tampering by escorting outside maintenance personnel throughout their service visit and visually inspecting their work before final acceptance of the service. Alternatively, building owners and managers can use reliable, prescreened service personnel from a trusted contractor.
8. *Restrict access to building information.*
Strictly control mechanical, electrical, vertical transport, fire and life safety, security system plans and schematics, and emergency operations procedures, preferably by developing and using an access list with controlled copy numbering.

9. *Consider other general building physical security upgrades.*

In addition to security measures for HVAC and other building operations, other physical security upgrades may be appropriate such as security fencing and controlled access points, with layered levels of security access to increasingly sensitive areas of the building.

Ventilation and Filtration

The quality and operation of HVAC systems and their components affect the vulnerability of a building to the introduction of CBR agents. Below are summaries of the NIOSH recommendations for evaluating HVAC control options, assessing filtration, using ducted and nonducted return-air systems, using low-leakage, fast-acting dampers, and building air tightness.

1. *Evaluate HVAC control options.* ***

Many central HVAC systems have energy management and control systems that can regulate airflow and pressures within a building on an emergency response basis. Some modern fire alarm systems may also provide useful capabilities during CBR events. In some cases, the best response option (given sufficient warning) might be to shut off the building's HVAC and exhaust system(s), thus avoiding the introduction of a CBR agent from outside. In other cases, interior pressure and airflow control may prevent the spread of a CBR agent released in the building and/or ensure the safety of egress pathways. The decision to install emergency HVAC control options should be made in consultation with a qualified HVAC professional who understands the ramifications of various HVAC operating modes on building operation and safety systems. Depending on the design and operation of the HVAC system and the nature of the CBR agent release, HVAC control may not be appropriate in all emergency situations. Lobbies, loading docks, and mailrooms might be provided with manually operated exhaust systems, activated by trained personnel to remove contaminants in the event of a known release, exhausting air to an appropriate area. In other instances, manipulation of the HVAC system could minimize the spread of an agent. If an HVAC control plan is pursued, building personnel should be trained to recognize a terrorist attack quickly and to know when to initiate the control measures. For example, emergency egress stairwells should remain pressurized (unless they are known to contain the CBR source). Other areas, such as laboratories, clean rooms, or pressure isolation rooms in hospitals, may need to remain ventilated. All procedures and training associated with the control of the HVAC system should be addressed in the building's emergency response plan.

2. *Assess filtration.* ***

Increasing filter efficiency is one of the few measures that can be implemented in advance to reduce the consequences of both an interior and exterior release of a particulate CBR agent. However, the decision to increase efficiency should be made cautiously, with a careful understanding of the protective limitations resulting from the

upgrade. The filtration needs of a building should be assessed with a view to implementing the highest filtration efficiency that is compatible with the installed HVAC system and its required operating parameters. In general, increased filter efficiency will provide benefits to the indoor environmental quality of the building. However, the increased protection from CBR aerosols will occur only if the filtration efficiency increase applies to the particle size range and physical state of the CBR contaminant. It is important to note that particulate air filters are used for biological and radiological particles and are not effective for gases and vapors typical of chemical attacks. These types of compounds require adsorbent filters (i.e., activated carbon or other sorbent-type media) and result in substantial initial and recurring costs.

Upgrading filtration is not as simple as merely replacing a low-efficiency filter with a higher-efficiency one. Typically, higher-efficiency filters have a higher pressure loss, which will result in some airflow reduction through the system. The magnitude of the reduction is dependent on the design and capacity of the HVAC system. If the airflow reduction is substantial, it may result in inadequate ventilation, reductions in heating and cooling capacity, or potentially frozen coils. To minimize pressure loss, deep pleated filters or filter banks having a larger nominal inlet area might be feasible alternatives, if space allows. Also, high-pressure losses can sometimes be avoided by using prefilters or more frequent filter changeouts. Pressure loss associated with adsorbent filters can be even greater.

The integrity of the HVAC system's filter rack or frame system has a major impact on the installed filtration efficiency. Reducing the leakage of unfiltered air around filters, caused by a poor seal between the filter and the frame, may be as important as increasing filter efficiency. If filter bypass proves to be significant, corrective actions will be needed. Some high-efficiency filter systems have better seals and frames constructed to reduce bypass. During an upgrade to higher-efficiency filters, the HVAC and filtration systems should be evaluated by a qualified HVAC professional to verify proper performance.

While higher filtration efficiency is encouraged and should provide indoor air-quality benefits beyond an increased protection from CBR terrorist events, the overall cost of filtration should be evaluated. Filtration costs include the periodic cost of the filter media, the labor cost to remove and replace filters, and the fan energy cost required to overcome the pressure loss of the filters. While higher-efficiency filters tend to have a higher life cycle cost than lower-efficiency filters, this is not always the case. With some higher-efficiency filter systems, higher acquisition and energy costs can be offset by longer filter life and a reduced labor cost for filter replacements. Also, improved filtration generally keeps heating and cooling coils cleaner and thus may reduce energy costs through improvements in heat transfer efficiency. However, when high-efficiency particulate air (HEPA) filters and/or activated carbon adsorbers are used, the overall costs will generally increase substantially.

3. *Ducted and nonducted return air systems.*

Nonducted return-air systems commonly use hallways or spaces above dropped ceilings as a return-air path or plenum. CBR agents introduced at any location above the

dropped ceiling in a ceiling plenum return system will most likely migrate back to the HVAC unit and, without highly efficient filtration for the particular agent, redistribute to occupied areas. Ducted returns offer limited access points and opportunities to introduce a CBR agent, especially if return vents are placed in conspicuous locations. Where ducted returns are not feasible or warranted, hold-down clips may be used for accessible areas of dropped ceilings that serve as the return plenum. This issue is closely related to the isolation of lobbies and mailrooms, as shared returns are a common way for contaminants from these areas to disperse into the rest of the building. Buildings should be designed to minimize mixing between air-handling zones, which can be partially accomplished by limiting shared returns. These modifications may be more feasible for new building construction or those undergoing major renovation.

4. *Low-leakage, fast-acting dampers.*

Rapid response, such as shutting down an HVAC system, may also involve closing various dampers, especially those controlling the flow of outdoor air (in the event of an exterior CBR release). When the HVAC system is turned off, the building pressure compared to outdoors may still be negative, drawing outdoor air into the building via many leakage pathways, including the HVAC system. Consideration should be given to installing low-leakage dampers to minimize this flow pathway. Damper leakage ratings are available as part of the manufacturer's specifications and range from ultra-low to normal categories. Assuming some warning prior to a direct CBR release, the speed with which these dampers respond to a "close" instruction can also be important. From a protective standpoint, dampers that respond quickly are preferred over dampers that might take 30 seconds or more to respond.

5. *Building air tightness.*

Infiltration of air through unintentional leakage paths in the building envelope can be of concern for exterior CBR releases at some distance from a building, such as a large-scale attack. Although increasing air tightness can be more challenging for an existing building than during new construction, it should still be seriously considered. In-leakage can be reduced by a combination of tight building construction and building pressurization. Building protection is more likely to be effective for a pressurized, tight building with a filtration system that is appropriate for the CBR agent introduced.

Maintenance, Administration, and Training

Maintenance of ventilation systems and training of staff are critical for controlling exposure to airborne contaminants, such as CBR agents. Major program elements are:

1. *Emergency plans, policies, and procedures.****

All buildings should have current emergency plans to address fire, weather, and other types of emergencies, including CBR attack. There should be associated procedures for communicating instructions to building occupants, identifying suitable shelter-in-place areas (if they exist), identifying appropriate use and selection of personal protec-

tive equipment (i.e., clothing, gloves, respirators), and directing emergency evacuations. Individuals developing emergency plans and procedures should recognize that there are fundamental differences between chemical, biological, and radiological agents. In general, chemical agents will show a rapid onset of symptoms, while the response to biological and radiological agents will be delayed. Issues such as designated areas and procedures for chemical storage, HVAC control or shutdown, and communication with building occupants and emergency responders should all be addressed. The plans should be as comprehensive as possible, but, as described earlier, protected by limited and controlled access. When appropriately designed, these plans, policies, and procedures can have a major impact on occupant survivability in the event of a CBR release. Staff training, particularly for those with specific responsibilities during an event, is essential and should cover both internal and external events. Holding regularly scheduled practice drills, similar to the common fire drill, allows for plan testing, as well as occupant and key staff rehearsal of the plan, and increases the likelihood for success in an actual event. For protection systems in which HVAC control is done via the energy management and control system, emergency procedures should be exercised periodically to ascertain that the various control options work (and continue to work) as planned.

2. *HVAC maintenance staff training.* ***

Periodic training of HVAC maintenance staff in system operation and maintenance should be conducted. This training should include the procedures to be followed in the event of a suspected CBR agent release, health and safety aspects for maintenance personnel, and the potential health consequences to occupants of poorly performing systems. Current, accurate HVAC diagrams and HVAC system labeling protocols should be developed and maintained. These documents can be of great value in the event of a CBR release.

3. *Preventive maintenance and procedures.* ***

Procedures and preventive maintenance schedules should be implemented for cleaning and maintaining ventilation system components. Replacement filters, parts, and so forth should be obtained from known manufacturers and examined prior to installation. It is important that ventilation systems be maintained and cleaned according to the manufacturer's specifications. To do this requires information on HVAC system performance, flow rates, damper modulation and closure, sensor calibration, filter pressure loss, filter leakage, and filter change-out recommendations. These steps are critical to ensure that protection and mitigation systems, such as particulate filtration, operate as intended.

Protecting Emergency Responders: Lessons Learned from Terrorist Attacks

Experience from the 1995 attack on the Alfred P. Murrah Federal Building in Oklahoma City, the September 11 attacks on the World Trade Center and the Pentagon, and the

anthrax incidents that occurred during autumn 2001 has provided a number of valuable lessons about protecting the health and safety of emergency responders. Many of these lessons were articulated and shared in December 2001 when NIOSH sponsored and asked the RAND Science and Technology Policy Institute to organize a conference of individuals with firsthand knowledge of emergency response to terrorist attacks. The purpose of the conference was to review the adequacy of personal protective equipment (PPE) and practices, such as training, and to make recommendations on how the equipment and practices worked and how they might be improved. Key recommendations from the conference report (Jackson et al. 2002) are presented in the following sections. These recommendations provide a cautionary perspective, as well as a path forward for anyone wishing to understand and overcome the special needs and current limitations for PPE to protect emergency responders during terrorist attacks.

Personal Protective Equipment Performance

- Develop guidelines for the appropriate PPE ensembles for long-duration disaster responses involving rubble, human remains, and a range of respiratory threats. If appropriate equipment is not currently available, address any roadblocks to its development. Such equipment could be applicable to other major disasters, such as earthquakes or tornadoes, as well as to terrorist attacks.
- Define the appropriate ensembles of PPE needed to safely and efficiently respond to biological incidents, threats, and false alarms. Key considerations include providing comparable levels of protection for all responders and addressing the logistical and decontamination issues associated with large numbers of responses in short time periods.

Personal Protective Equipment Availability

- Explore mechanisms to effectively outfit all responders at large incident sites with appropriate personal protective equipment as rapidly as possible.
- Examine any barriers to equipment standardization or interoperability among emergency-responder organizations. Strategies could include coordination of equipment procurement among organizations or work with equipment manufacturers to promote broader interoperability within classes of equipment.

Training and Information

- Define mechanisms to rapidly and effectively provide responders at incident sites with useful information about the hazards they face and the equipment they need for protection. Approaches could include more effective coordination among relevant

organizations and development of technologies that provide responders with individual, real-time information about their environment.

- Explore ways to ensure that responders at large-scale disaster sites are appropriately trained to use the protective equipment they are provided. All types of responders must be addressed, and mechanisms that provide training and experience with the equipment before a disaster occurs should be investigated.
- Consider logistical requirements of extended response activities during disaster drills and training. Such activities provide response commanders with information on the logistical constraints that could restrict response capabilities.

Management

- Provide guidelines and define organizational responsibilities for enforcing protective-equipment use at major disaster sites. While such guidelines must address the risks responders are willing to take when the potential exists to save lives, they must also consider that during long-term responses, the health and safety of responders should be a principal concern.
- Develop mechanisms to allow rapid and efficient scene control at disaster sites as early as possible during a response.

Protecting Emergency Responders: Community Views of Safety and Health Risks and Personal Protection Needs

In fiscal year 2001, Congress allocated funds for NIOSH to establish a new program for personal protective technology research to protect the nation's miners, firefighters and other emergency responders, and healthcare, agricultural, and industrial workers. To carry out this research, NIOSH formed the National Personal Protective Technology Laboratory (NPPTL). The Laboratory's mission, like the mission of its parent organization, is to provide world, national, and institute leadership for prevention and reduction of occupational disease, injury, and death but with special emphasis on those workers who rely on personal protective technologies. The NPPTL is engaged in an active program of research, standards development, respirator certification, and information dissemination. For example, NPPTL recently developed test methods and standards for open-circuit, self-contained breathing apparatus, gas masks and escape respirators that could be used in the event of a chemical, biological, radiological, or nuclear terrorist attack (www.cdc.gov/niosh/npptl).

In follow-up to the 2002 report on lessons learned for protecting emergency responders, NPPTL asked the RAND Science and Technology Policy Institute to develop a second report (LaTourrette et al. 2003) to present an overview of occupational hazards and personal protection needs as viewed by emergency responders in the United States. A key

finding was that providing protection for CBR terrorism is complicated by several uncertainties:

- Many police and fire department representatives felt that they did not know what they need to be protected against, what form of protection is appropriate, or where to look for such protection. Such uncertainty frustrates efforts to design a protection program and acquire the necessary technology.
- Participants were unsure how well the available protective technologies will work for anticipated situations. While hazardous materials (hazmat) protection is subject to rigorous standards and certification procedures, hazmat equipment and usage protocols are designed primarily around the conventional model of hazmat response to industrial accidents. Much of the available hazmat protection is neither designed nor certified for this new role of terrorism response.

Personal Protection Priorities and Recommendations Raised by the Emergency Responder Community

Priorities, recommendations, and policy areas raised by the emergency responder community included the need to:

- *Reduce physical stress and improve comfort* by improving garment breathability, reducing equipment weight, ensuring consistent and appropriate sizing of components, and enhancing ergonomic characteristics.
- *Improve communications* by making radio systems interoperable, improving communications capabilities with self-contained breathing apparatus (SCBA), and improving radio design to allow hands-free use and use with gloves.
- *Upgrade communicable disease protection* to increase protective equipment options for emergency medical service (EMS) personnel and police.
- *Develop practical respiratory and chemical protection equipment and guidelines for first responders*, including improving the chemical and biological protection of garments and respirators, designing protective equipment such that it minimizes interference with responder activities, and requiring more chemical/biological hazard training.
- *Improve personal protective technology (PPT) standby performance* by developing integrity monitoring and service-life monitoring technologies, enhancing compactness and portability of protective equipment, addressing logistical complications, and reducing protective equipment maintenance complexity and cost.
- *Expand training and education* by requiring more training on sophisticated protective equipment and reducing the complexity of new equipment.
- *Benchmark best safety practices*, particularly for EMS and police, and study and benchmark PPT enforcement practices.

Key Policy Areas and Issues Raised by the Emergency Responder Community

Key policy issues were raised in six areas:

- *PPT research and development*: Research should be more strategic and multidimensional, including more fundamental, long-term research; greater emphasis on ensembles is needed; research and development should address response activity rather than services; and decentralized market limiting innovation and purchasing power should be addressed.
- *Discretion in personal protection decision making*: The expanding role of emergency responders and improved hazard assessment warrant increased attention to activity-specific tailoring of protection.
- *PPT standards for emergency medical services and law enforcement*: EMS and police communities need dedicated personal protection, safety, and standardization efforts.
- *PPT performance assessment*: Reliable and objective equipment performance assessments need to be developed.
- *PPT standardization and interoperability*: Mutual-aid agreements and extended operations should be facilitated by enhanced standardization and interoperability.
- *The role of risk in emergency response*: Emergency responders' perceptions of and their responses to risks inherent in emergency response should be examined and efforts should be promoted to decrease risk through improved information management, clarified protocols, and improved equipment.

Recommendations for Respiratory Protection and Personal Protective Technologies

Specific NIOSH guidelines and information about respiratory protection and personal protective technologies can be found at the NPPTL Website (www.cdc.gov/niosh/npptl). This includes the results of a voluntary survey of U.S. employers regarding the use of respiratory protection that was conducted by NIOSH and the U.S. Department of Labor's Bureau of Labor Statistics (NIOSH 2001); links to the two NIOSH-sponsored reports on the need for research, training, and other strategic approaches to help protect emergency responders in terrorist attacks (Jackson 2002; LaTourrette 2003); downloadable software for predicting air-purifying respirator filter cartridge service life (NIOSH 2003b); a respirator fact sheet on what you should know in deciding whether to buy escape hoods, gas masks, or other respirators for preparedness at home and work (NIOSH 2003c); a series of articles that offer guidance for protecting healthcare workers from exposure to SARS (severe acute respiratory syndrome) (NIOSH 2003d); and information on how to determine whether an SCBA respirator is NIOSH-certified for chemical, biological, radiological, and nuclear (CBRN) environments (NIOSH 2004). Announcements of new developments are

also posted. For example, on 26 February 2004 it was announced that DHS had adopted, as DHS standards, three NIOSH criteria for testing and certifying respirators for protection against CBRN exposures. NIOSH uses the criteria to test (1) self-contained breathing apparatus (SCBA) for use by emergency responders against CBRN, (2) air-purifying respirators for use by emergency responders against CBRN exposures, and (3) escape respirators for protection against CBRN. A list of NIOSH-approved CBRN respirators can be found at the same NPPTL Website (www.cdc.gov/niosh/npptl).

Considerations for Dirty Bombs

In its “Fact Sheet on Dirty Bombs” (U.S. NRC 2003), the U.S. Nuclear Regulatory Commission (NRC) provided information to the public on what a dirty bomb is and what terrorists might intend to accomplish in setting off such a weapon. The fact sheet noted that certain radioactive materials, dispersed in the air, could contaminate up to several city blocks, creating fear and possibly panic and requiring potentially costly cleanup. People were advised to take these steps following an explosion:

1. Move away from the immediate area — at least several blocks from the explosion — and go inside. This will reduce exposure to any radioactive airborne dust.
2. Turn on local radio or television channels for advisories from emergency response and health authorities.
3. If facilities are available, remove clothes and place them in a sealed plastic bag. Saving contaminated clothing will allow testing for radiation exposure.
4. Take a shower to wash off dust and dirt. This will reduce total radiation exposure, if the explosive device contained radioactive material.
5. If radioactive material was released, local news broadcasts will advise people where to report for radiation monitoring and blood and other tests to determine whether they were in fact exposed and what steps to take to protect their health.

Implicit in the first recommendation is the basic premise that the concentration of airborne and other contamination is expected to be lower inside buildings.

Mitigating Multihazard Events

The Federal Emergency Management Agency (FEMA) has developed a Risk Management Series of documents directed at providing design guidance for mitigating multihazard events (available online at <http://www.fema.gov/fima/rmsp.shtm>). This adds guidance for man-made disasters to the previously available publications on dealing with earthquakes, floods, high winds, and other natural disasters. The objective of the new series is to reduce physical damage to structural and nonstructural components of buildings and related infrastructure and to reduce casualties during conventional bomb attacks, as well as attacks

using CBR agents. Using many principles from the NIOSH guidance documents, FEMA builds on the premise that improving security in high-occupancy buildings will better protect the nation from potential threats by identifying key actions and design criteria to strengthen our buildings from the forces that might be anticipated in a terrorist assault.

FEMA 426 *Reference Manual to Mitigate Potential Terrorist Attacks Against Buildings* provides guidance to the building science community of architects and engineers to reduce physical damage to buildings, related infrastructure, and people caused by terrorist assaults. The manual presents incremental approaches that can be implemented over time to decrease the vulnerability of buildings to terrorist threats. The manual states that many of the recommendations can be implemented quickly and cost-effectively. FEMA 426 contains many how-to aspects based on current information contained in FEMA, Department of Commerce, Department of Defense, Department of Justice, General Services Administration, Department of Veterans Affairs, Centers for Disease Control and Prevention/National Institute for Occupational Safety and Health, and other publications. The manual describes a threat assessment methodology and presents a Building Vulnerability Assessment Checklist to support the assessment process. It also discusses architectural and engineering design considerations, stand-off distances, explosive blast, and CBR information. Appendices in the manual include a glossary of CBR definitions as well as general definitions of key terminologies used in the building science security area. The appendices also describe design considerations for electronic security systems and provide a listing of associations and organizations currently working in the building science security area.

FEMA 427 *Primer for Design of Commercial Buildings to Mitigate Terrorist Attacks* introduces a series of concepts that can help building designers, owners, and state and local governments mitigate the threat of hazards resulting from terrorist attacks on new buildings. The primer specifically addresses four high-population, private-sector building types: commercial office, retail, multifamily residential, and light industrial. It contains extensive qualitative design guidance for limiting or mitigating the effects of terrorist attacks, focusing primarily on explosions, but also addressing CBR attacks.

FEMA 428 *Primer to Design Safe School Projects in Case of Terrorist Attacks* provides the design community and school administrators with the basic principles and techniques to make a school that is safe from terrorist attacks. FEMA 428 includes information on how to conduct a threat/risk assessment, prepare site layout and building design, and create school safety plans. It also includes a brief discussion on blast theory and CBR measures that can be taken to mitigate school vulnerabilities, as well as a stand-alone description of the concept of safe rooms within schools that will resist CBR and blast threats.

FEMA 429 *Insurance, Finance, and Regulation Primer for Terrorism Risk Management in Buildings* introduces the building insurance, finance, and regulatory communities to the issue of terrorism risk management in buildings and the tools currently available to manage the risks. FEMA 429 provides information related to insurance, the Terrorism Risk Insurance Act of 2002, and highlights current building regulations related to terrorism risk, due diligence, and vulnerability. The manual also includes a Building Security Checklist categorized by data collection, attack delivery methods, and attack mechanism parameters.

FEMA also offers course E155 entitled *Building Design for Homeland Security* to familiarize students with assessment methodologies available to identify the relative level of risk for various threats, including blast and CBR. FEMA E155 course materials are available for download from the FEMA Website.

Developing and Communicating Effective Guidelines

Issues of costs, benefits, competing goals, and tradeoffs influence the strategy and content of guidance for respiratory and ventilation protection against weapons of mass destruction. No single consideration can be evaluated or addressed in a vacuum. For example, a recent report by the ASHRAE Presidential Study Group on Health and Safety under Extraordinary Incidents (ASHRAE 2002) recommended that ASHRAE should NOT consider requiring, or even recommending, that buildings be designed to enhance safety under extraordinary incidents without careful consideration of such parameters as initial and maintenance costs, energy consumption, indoor air quality, and site adaptability. Society must live with its choices on a daily basis, including fundamental concerns for efficacy, affordability, and sustainability.

As noted above in the NRC recommendations, in conjunction with any terrorist event it will be important to listen for advisories from emergency response and health authorities. The airborne dispersion and other characteristics of each terrorist or emergency event will differ and incident-specific guidance is likely to be needed. A recent white paper from the American Nuclear Society to the U.S. Department of Homeland Security provides a scientific basis for a communications action plan on the subject of radiological dispersion device events (ANS 2003). Issues of aerosol dispersion are taken into account in the white paper recommendation to classify the many different types of RDDs into three categories based on the type of hazard they present: (1) external and internal hazard (for example, cesium); (2) primarily internal hazard (for example, strontium or respirable plutonium); and (3) external hazard only (for example, cobalt). Advanced planning is recommended to develop information on past accidental dispersion of radioactive material and to explore new communications technologies. The white paper also emphasizes the need for consistent information from public officials, the medical community, law enforcement, and others to the public. The report notes that DHS can help to ensure that state and local officials have the tools and background to be able to say that they know the right course of action, based on information given to them by experts.

Conclusion

A developing body of guidance currently exists for preparing and implementing respiratory and ventilation protection against airborne weapons of mass destruction. The general principles of aerosol behavior, combined with potential or actual terrorist intents and

actions, combine to shape existing strategies. Significant opportunities remain to integrate aerosol knowledge and protective strategies from the ground up into personal, business, community, government, and global activities.

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