

# ECRI ADVISORY

## Selecting Personal Protective Equipment for Chemical and Bioterrorism Preparedness: Risks and Costs

Healthcare facilities have many decisions to make in deciding how to budget their share of the \$135 million dollars recently appropriated by Congress to hospitals for chemical and bioterrorism preparedness. This is particularly true in selection, use, and maintenance of appropriate personal protective equipment (PPE) for frontline healthcare worker use in emergency response.

A thorough understanding of the inherent hazards and limitations associated with the various types of respiratory protective devices, as well as with chemical-resistant suits, gloves, and boots, is necessary for a facility to select the most appropriate PPE for the protection of patients and staff. ECRI issues the following overview and recommendations regarding PPE and respiratory protection for healthcare workers involved in emergency response. Level A protection, which provides the highest degree of respiratory and skin protection by providing the user with a fully encapsulated and chemically impervious environment, is not typically recommended for frontline healthcare workers in emergency response and so will not be addressed here.

### Level B Respiratory Protection

The Occupational Safety and Health Administration (OSHA) requires a Level B ensemble as the *minimum* level of protection for first responders, including frontline healthcare workers, *if the chemical or biologic agent and/or exposure concentration is unknown*. Level B protection includes a splash protective suit (e.g., Saranex®) and a positive-pressure supplied-air respirator such as an airline respirator or self-contained breathing apparatus (SCBA). Level B can be downgraded to Level C protection, in which full- or half-face air-purifying respirator use is recommended, after the contaminant and concentration has been identified.

The use of PPE, particularly Level B, can present a significant risk to users, particularly those who are not properly trained and medically evaluated, fit tested, and approved to use the equipment under actual hazardous conditions. Employee health hazards associated with PPE and respirator use include increased cardiac demand and respiratory fatigue,

increased body temperature and heat stress, claustrophobia, and posttraumatic stress disorder. There are also ergonomics and human factors issues to consider, including prolonged reaction and performance time, loss of balance, and risk of lower back injury. A brief discussion of the various types of respirators and how they work will be useful in understanding the risks involved in their use. Recommendations will be offered to help healthcare facilities establish measures to mitigate these risks to healthcare workers.

### Supplied-Air Respirators

There are two major subdivisions of supplied-air respirators: the airline respirator and the SCBA. Although both supply Grade D air (the purity level of which is defined by the Compressed Gas Association in its publications CGA G-7 "Compressed Air for Human Respiration" and CGA G-7.1 "Commodity Specification for Air") or better, can be fitted with a tight or hood-style facepiece, and have characteristic OSHA and National Institute for Occupational Safety and Health (NIOSH) requirements, each has inherent attributes and limitations that can affect a healthcare worker's ability to respond to an emergency situation.

**Airline Respirators.** Healthcare workers using an airline respirator are on a tether (the airline) that is attached to a freestanding air supply from an air pump, compressor, or compressed gas cylinder. Air delivery can be accomplished through demand, pressure demand, or continuous flow. Demand units provide air upon inhalation, creating negative pressure within the mask, which conserves air but requires more physical exertion and can allow toxicants in the ambient atmosphere to leak into the mask at the facial seal. Pressure demand systems are also activated by inhalation from the user; once activated, however, positive pressure is maintained in the facepiece and is increased with user inhalation. Continuous-flow systems provide 4 to 15 cubic feet per minute airflow continuously to the user upon activation.

Air pumps and compressors can fail in contaminated atmospheres. To protect users in the event an air supply fails, airline respirators should be fitted with an appropriate air-purifying cartridge and/or a supplemental air bottle for escape.

Only air compressors that supply the user with Grade D breathing or better should be used. Compressed gas cylinders must be secured to the wall or in an appropriate free-standing cart and be equipped with reliable regulators. Airline respirator users must also exercise caution because the airline itself limits movement somewhat and can present a tripping hazard if not configured properly. Airline respirators are probably best suited for situations in which emergency patient care is limited to a small area, such as in a decontamination or isolation/treatment room.

**Self-Contained Breathing Apparatus.** The two major types of SCBAs are open and closed circuit. Open-circuit systems usually consist of a Grade D tank of compressed air that lasts 30 to 120 minutes and exhausts the exhaled air directly into the atmosphere. Closed-circuit SCBAs are usually smaller and are comprised of highly compressed or liquid oxygen and a device that removes carbon dioxide from the exhaled air within the unit and adds oxygen to replace the oxygen that has been used. Closed-circuit SCBAs typically allow up to four hours of use. SCBA units approved for firefighting can be either open or closed circuit and can weigh 45 pounds or more. SCBAs not approved for firefighting are open circuit and typically weigh approximately 20 to 25 pounds.

Although an SCBA with a tight-fitting, full facepiece has the highest NIOSH-approved protection factor (APF),\* these devices are costly and are not without inherent hazards and limitations. SCBA use can cause incomplete gas exchange and can make breathing more difficult, which may lead to respiratory muscle fatigue and chest compression. An SCBA also adds a considerable amount of weight to a healthcare worker's body, posing an ergonomic challenge to the user, particularly when handling and lifting incapacitated patients. Worn over extended periods, the weight of the SCBA can cause shoulder and back muscle fatigue and lower back injury.

An SCBA also places special demands on motor skills, affects posture, and changes the user's center of gravity, all of which can lead to loss of balance and adversely affect performance of patient care. As is the case with many hooded or full-face respirators, the SCBA's user's visual field is limited to varying degrees, which further affects the user's postural control and balance. Depending on the particular SCBA, other inherent hazards include fire, explosion, compression hazards of compressed air, pinch points when attaching cylinders and hoses, and failure of integral parts such as the face lens. For these reasons, healthcare facilities should carefully weigh their need for an SCBA against the inherent hazards associated with its use, as well as consider the initial and maintenance costs of the apparatus, ease of use, fit testing, and

training before purchasing such equipment. If SCBAs are deemed necessary, facilities should look for lightweight pressure demand units that can be donned, removed, and stored easily.

## Level C Respiratory Protection

As noted earlier, Level C protection entails use of a full- or half-face air-purifying respirator once the contaminant and its concentration have been identified.

### Air-Purifying Respirators

Air-purifying respirators remove contaminants by filtering air in the user's breathing zone instead of supplying air from a remote source such as an air tank or compressor. Air-purifying respirators can filter particulate, chemical vapors and mists or a combination of both. Filtering facepiece particulate respirators are designated as N (not resistant to oil), R (resistant to oil), or P (oil proof) and have efficiencies of 95%, 99%, and 99.97%.

**The N95 Particulate Respirator.** The N95 respirator is commonly used in healthcare settings as part of standard precautions against transmission of airborne infections. This model affords protection from infectious aerosols (e.g., tuberculosis) and particulate but is not effective in atmospheres that have been contaminated with volatile organic chemical compounds and can be more easily dislodged and wetted during decontamination and treatment activities.

**Air-Purifying Respirators.** Air-purifying respirators fitted with high-efficiency particulate air (HEPA) cartridges or canisters can protect against particles such as biological spores, asbestos fibers, dusts, and fumes. HEPA cartridges remove 99.97% of particles with an average diameter of 0.3 microns. Air-purifying respirators fitted with chemical-specific cartridges or canisters provide protection against chemical vapors and mists. Combination cartridges and canisters combine the protective characteristics of HEPA filtration and chemical-specific capture. In either case, air-purifying respirators are available in half-face and full-face units and have an APF of 10 and 50, respectively.\*\* Those whose function depends solely on the inhalation and exhalation of the user are considered negative-pressure air-purifying respirators. As with other respirators, these air-purifying respirators can increase cardiopulmonary strain and can cause user fatigue.

**Powered Air-Purifying Respirators (PAPRs).** PAPRs also filter the ambient air, but these units use a battery-powered

\* The APF of a respirator reflects the level of protection that a properly functioning respirator would be expected to provide to a population of properly fitted and trained users.

\*\* An APF of 10 for a respirator means that a user could expect to inhale no more than one-tenth of the airborne contaminant present.

motor and blower to supply air to the user through a hose to a half- or full-face facepiece or loose-fitting hood/helmet. The battery life is typically 8 to 10 hours using nickel-cadmium (NiCd) or lithium technology. The blower produces a positive pressure in the face or headpiece, lowering the likelihood of inward leakage, providing a higher degree of protection (an APF between 25 and 50 according to NIOSH and as much as 1000 according to manufacturers), reducing cardiopulmonary strain and fatigue, and affording the user greater cooling capacity. PAPRs with highly chemical-resistant hoods (e.g., butyl rubber) are typically much easier to take on and off, are versatile for emergency response because they can often be fitted to an airline or supplied air tank, and are more convenient because they do not require user fit testing.

## Protective Clothing

Certain protective clothing offers protection against particulates and fibers, while others offer chemical resistance. Risks are associated with each type. Level B suits are spun-bonded and coated with polyethylene, polyvinyl chloride, or Saran, for example, providing good chemical resistance but posing considerable risk for the user, who may experience heat stress. Uncoated spun-bonded garments such as those used in Level C are good for particulate and fiber exposure, are breathable, and reduce the likelihood of heat stress but are normally not chemical or liquid resistant. Other integral components of protective clothing including chemical-resistant gloves and boots can also increase body temperature and sweating, contributing to heat stress, dehydration, skin irritation, rashes, and fungal infections.

## Staffing

A team of appropriately trained and equipped healthcare workers who can safely triage, decontaminate, and treat victims without endangering themselves and contaminating the facility should be maintained on-site. At a minimum, this would require that several staff members on each shift be provided with and trained in the use of the appropriate equipment for Level B protection. Because of the characteristics of PPE use that can affect healthcare workers physical and mental status in emergency situations, healthcare facilities should train sufficient numbers of additional staff in PPE use to allow for rotation in and out of the area during emergency operations. The OSHA requirement that there be a one-to-one correspondence between responders in Level A and their backup is an equally prudent practice for Level B response as well and should be strongly considered.

## ECRI Recommendations

- Account for human factors in selection and purchase of PPE and respiratory protection, such as user comfort, body burden, and susceptibility to heat stress, as well as considerations such as contaminant resistance properties of protective ensembles, respirator class, APF, and the configurations and shelf life of cartridges.
- Account for the fact that each person slated to use tight-fitting respirators must be, at a minimum, qualitatively fit tested for *each specific respirator model and size* of the units potentially used, requiring approximately 10 to 15 minutes per respirator per person for fit-testing to be performed. Non-tight-fitting units such as hooded PAPRs do not require fit testing.
- Train healthcare workers how to mitigate potentially harmful effects of PPE use, including use of controlled breathing techniques, recognition of signs and symptoms of heat stress, the need for rest periods and hydration, emergency procedures, practical exercises, and fitness tips in addition to PPE operation and maintenance, inspection, cleaning and decontamination of equipment, donning and doffing procedures, safety checks, checking end-of-service-life indicators, and changing of air-purifying respirator air cylinders or cartridges.
- Design and conduct disaster drills so healthcare workers don and remove PPE to experience conditions that simulate some of the physical and mental challenges of conducting patient care tasks while wearing each PPE ensemble.
- Establish a medical surveillance program for personnel responsible for PPE use for decontamination, triage, and first response for collection of baseline medical data for future comparison. Include the following:
  - Medically evaluate their physical and mental fitness for duty, including assessment of the ability to work extended periods in Level B ensemble.
  - Conduct physical exams to note susceptibility factors (e.g., obesity) and any physical limitations to wearing PPE, such as facial configurations (e.g., scarring, facial hair) that would preclude an adequate seal for use of tight-fitting facepiece respirators.
  - Use occupational and medical history questionnaires to assess (1) prior occupational exposure to nuclear, biological, chemical, and physical agents; (2) past illnesses; (3) atopic diseases (e.g., eczema, asthma, lung and cardiovascular diseases); (4) symptoms (e.g., shortness of breath, labored breathing with exertion, high blood pressure, heat intolerance, chest pain, chronic respiratory symptoms); (5) sensitivity and/or susceptibility to

certain substances; and (6) nonoccupational factors including lifestyle habits and hobbies.

- Develop a heat stress program for emergency response based on current OSHA recommendations (available on the Internet at [www.osha.gov](http://www.osha.gov)), and ensure that supplies of potable water are available for healthcare workers to replenish fluids during emergencies.

*This advisory was prepared by ECRI's Center for Healthcare Environmental Management (CHEM), a membership program that provides information, education, and professional certification to healthcare environmental health, safety, and security managers. This advisory is available on the ECRI Web site ([www.ecri.org](http://www.ecri.org)).* ♦

**About ECRI**

ECRI ([www.ecri.org](http://www.ecri.org)) is an independent, nonprofit healthcare organization dedicated to improving the safety, efficacy, and cost-effectiveness of health technology, broadly defined to encompass devices, drugs, procedures, facilities, and related standards and guidelines. The agency works to inform the healthcare community of improved methods of patient care and protect the public from unsafe and ineffective medical technologies and practices.

ECRI is a Collaborating Center of the World Health Organization (WHO) and recently received expanded status in recognition of its efforts in healthcare risk and quality management. ECRI now serves as the WHO Healthcare Standards and Guidelines Archives. The U.S. Agency for Healthcare Research and Quality has designated ECRI an Evidence-based Practice Center.

ECRI's services alert members to technology related hazards; disseminate results of medical product evaluations and technology

assessments; provide expert advice on technology acquisitions, staffing, and management; report on hazardous materials, management policy and practices; and supply authoritative information on risk control in healthcare facilities and clinical practice guidelines and standards.

**About CHEM**

CHEM, sponsored by ECRI, is a national professional organization dedicated to providing continuing education and certification for healthcare occupational safety and environmental managers. ECRI and CHEM sponsor the premier nationally recognized certification program in healthcare safety, security, and environmental management for the healthcare professional. Certification in healthcare environmental management provides the opportunity to gain professional acknowledgement and recognition of expertise and experience in the occupational health and safety field. Certification courses are held across the country. Visit ECRI's Web site for more information and course dates.

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