CHEMICAL, BIOLOGICAL, AND RADIOLOGICAL MEASURES 5

This chapter is based on guidance from the CDC/NIOSH and the DoD and presents protective measures and actions to safeguard the occupants of a building from CBR threats. Evacuation, sheltering in place, personal protective equipment, air filtration and pressurization, and exhausting and purging will be discussed, as well as CBR detection[1]. Additionally, CBR design mitigation measures are discussed in Chapter 3 and Appendix C contains a glossary of CBR terms and a summary of CBR agent characteristics.

Recent terrorist events have increased interest in the vulnerability of buildings to CBR threats. Of particular concern are building HVAC systems, because they can become an entry point and distribution system for airborne hazardous contaminants. Even without special protective systems, buildings can provide protection in varying degrees against airborne hazards that originate outdoors. Conversely, the hazards produced by a release inside a building can be much more severe than a similar release outdoors. Because buildings allow only a limited exchange of air between indoors and outdoors, not only can higher concentrations occur when there is a release inside, but hazards may persist longer indoors.

After the presence of an airborne hazard is detected, there are five possible protective actions for a building and its occupants. In increasing order of complexity and cost, these actions are:

1. Evacuation
2. Sheltering in Place
3. Personal Protective Equipment
4. Air Filtration and Pressurization
5. Exhausting and Purging

[1]This chapter includes a number of protective measures that are included for informational purposes only. It is not the intention of FEMA to endorse any particular product or protective measure.

These actions are implemented, singly or in combination, when a hazard is present or known to be imminent. To ensure these actions will be effective, a protective-action plan specific to each building, as well as training and familiarization for occupants, is required. Exhausting and purging is listed last because it is usually the final action after any airborne hazard incident.

5.1 EVACUATION

Evacuation is the most common protective action taken when an airborne hazard, such as smoke or an unusual odor, is perceived in a building. In most cases, existing plans for fire evacuation apply. Orderly evacuation is the simplest and most reliable action for an internal airborne hazard. However, it may not be the best action in all situations, especially in the case of an external CBR release or plume, particularly one that is widespread. If the area covered by the plume is too large to rapidly and safely exit, sheltering in place should be considered. If a CBR agent has infiltrated the building and evacuation is deemed not to be safe, the use of protective hoods may be appropriate. Two considerations in non-fire evacuation are: 1) to determine if the source of the airborne hazard is internal or external, and 2) to determine if evacuation may lead to other risks. Also, evacuation and assembly of occupants should be on the upwind side of the building and at least 100 feet away, because any airborne hazard escaping the building will be carried downwind.

5.2 SHELTERING IN PLACE

In normal operations, a building does little to protect occupants from airborne hazards outside the building because outdoor air must be continuously introduced to provide a comfortable, healthy indoor environment. However, a building can provide substantial protection against agents released outdoors if the flow of fresh air is filtered/cleaned, or temporarily interrupted or reduced. Interrupting the flow of fresh air is the principle applied in the protective action known as sheltering in place.

The advantage of sheltering in place is that it can be implemented rapidly. The disadvantage is that its protection is variable and diminishes with the duration of the hazard. Sheltering requires that two distinct actions be taken without delay to maximize the passive protection a building provides:

- First, reduce the indoor-outdoor air exchange rate before the hazardous plume arrives. This is achieved by closing all windows and doors, and turning off all fans, air conditioners, and combustion heaters.

- Second, increase the indoor-outdoor air exchange rate as soon as the hazardous plume has passed. This is achieved by opening all windows and doors, and turning on all fans to ventilate the building.

The level of protection that can be attained by sheltering in place is substantial, but it is less than can be provided by high efficiency filtration of the fresh air introduced into the building. The amount of protection varies with:

- **The building's air exchange rate.** The tighter the building (i.e., the lower the air exchange rate), the greater the protection it provides. In most cases, air conditioners and combustion heaters cannot be operated while sheltering in place because operating them increases the indoor-outdoor exchange of air.

- **The duration of exposure.** Protection varies with time, diminishing as the time of exposure increases. Sheltering in place is, therefore, suitable only for exposures of short duration, roughly 2 hours or less, depending on conditions.

- **Purging or period of occupancy.** How long occupants remain in the building after the hazardous plume has passed also affects the level of protection. Because the building slowly purges contaminants that have entered it, at some point during plume passage, the concentration inside exceeds the concentration outside. Maximum protection is attained by

increasing the air exchange rate after plume passage or by exiting the building into clean air.

- **Natural filtering.** Some filtering occurs when the agent is deposited in the building shell or upon interior surfaces as air passes into and out of the building. The tighter the building, the greater the effect of this natural filtering.

In a home, taking the actions required for sheltering (i.e., closing windows and doors, and turning off all air conditioners, fans, and combustion heaters) is relatively simple. Doing so in a commercial or apartment building may require more time and planning. All air handling units must be turned off and any dampers for outside air must be closed. Procedures for a protective action plan, therefore, should include:

- Identifying all air handling units, fans, and the switches needed to deactivate them.

- Identifying cracks, seams, joints, and pores in the building envelope to be temporarily sealed to further reduce outside air infiltration. Keeping emergency supplies, such as duct tape and polyethylene sheeting, on hand.

- Identifying procedures for purging after an internal release (i.e., opening windows and doors, turning on smoke fans, air handlers, and fans that were turned off) to exhaust and purge the building.

- Identifying sheltering rooms (i.e., interior rooms having a lower air exchange rate) that may provide a higher level of passive protection. It may be desirable to go to a predetermined sheltering room (or rooms) and:

    - Shut and lock all windows and doors
    - Seal any windows and vents with plastic sheeting and duct tape

- Seal the door(s) with duct tape around the top, bottom, and sides
- Firmly pack dampened towels along the bottom of each door
- Turn on a TV or radio that can be heard within the shelter and listen for further instructions
- When the "all clear" is announced, open windows and doors

Important considerations for use of sheltering in place are that stairwells must be isolated by closed fire doors, elevators must not be used, and clear evacuation routes must remain open if evacuation is required. Escape hoods may be needed if the only evacuation routes are through contaminated areas.

One final consideration for sheltering in place is that occupants cannot be forced to participate. It is important to develop a plan in cooperation with likely participants and awareness training programs that include discussions of sheltering in place and events (CBR attacks, hazardous material releases, or natural disasters) that might make sheltering preferable to evacuation. During an event, some building protective action plans call for making a concise information announcement, and then giving occupants 3 to 5 minutes to proceed to the sheltering area or evacuate the building before it is sealed. Training programs and information announcements during an event should be tailored to help occupants to make informed decisions.

5.3 PERSONAL PROTECTIVE EQUIPMENT

A wide range of individual protection equipment is available, including respirators, protective hoods, protective suits, CBR detectors, decontamination equipment, etc. The DOJ, National Institute of Justice (NIJ), *Guide for the Selection of Personal Protective Equipment for Emergency First Responders* (NIJ Guide 102-00, Volumes I-IV) provides summarizes and evaluates a wide range of personal protective equipment. The U.S. Joint Service Materiel

Group (JSMG) has sponsored the Nuclear Biological Chemical (NBC) Industry Group to produce a catalogue of CBR products and services manufactured and provided by companies in the United States.

Of particular note, new models of universal-fit escape hoods have been developed for short-duration "escape-only" wear to protect against chemical agents, aerosols (including biological agents), and some toxic industrial chemicals. These hoods are compact enough to be stored in desks or to be carried on the belt. They should be stored in their sealed pouches and opened only when needed. Most of these hoods form protective seals at the neck and do not require special fitting techniques or multiple sizes to fit a large portion of the population. Training is required to use the hoods properly. Depending on hood design, the wearer must breathe through a mouth bit or use straps to tighten a nose cup around the nose and mouth (see Figure 5-1).

SOURCE: MSA INTERNATIONAL

Figure 5-1 Universal-fit escape hood

The protective capability and shelf life of these hoods varies with the design. The filters of the hoods contain both high efficiency particulate air (HEPA) filters and packed carbon beds, so they will remove chemical and biological aerosols, as well as chemical vapors and gases. Although the carbon filters are designed to filter a broad range of toxic chemicals, they cannot filter all chemicals. An important consideration in planning for use of escape hoods is that their filters are not effective against certain chemicals of high vapor pressure. Chemical masks provide no protection against carbon monoxide, which is produced in fires. Manufacturers' data should be

checked closely when ordering. Other escape hoods are available that employ compressed oxygen cylinders, rather than air filters, to provide eye and respiratory protection for very short periods.

There are no government standards for hoods intended for protection against the malicious use of chemical or biological agents. In selecting an escape hood, a purchaser should, therefore, require information on laboratory verification testing. Plans should be made for training, fitting, storing, and maintaining records relative to storage life, and there should be procedures for instructing building occupants as to when to put on the hoods. Wearing a mask can cause physiological strain and may cause panic or stress that could lead to respiratory problems in some people. Finally, it should be recognized that no single selection of personal protective equipment is effective against every possible threat. Selection must be tied to specific threat/hazard characteristics.

5.4 AIR FILTRATION AND PRESSURIZATION

Among the various protective measures for buildings, high efficiency air filtration/cleaning provides the highest level of protection against an outdoor release of hazardous materials. It can also provide continuous protection, unlike other approaches for which protective measures are initiated upon detecting an airborne hazard.

Two basic methods of applying air filtration to a building are external filtration and internal filtration. External filtration involves drawing air from outside, filtering and/or cleaning it, and discharging the air inside the building or protected zone. This provides the higher level of protection, but involves substantially higher costs. Internal filtration involves drawing air from inside the building, filtering and/or cleaning it, and discharging the air back inside the building.

The relative levels of protection of the two methods can be illustrated in terms of protection factor, and the ratio of external dose and internal dose (concentration integrated over time). External filtration systems with high efficiency filters can yield protection

factors greater than 100,000. For internal filtration, the protection factors are likely to be less and are highly variable. The protection of internal filtration varies with a number of factors, including those listed in sheltering in place, the efficiency of the filter, flow rate of the filter unit, and size of the room or building in which the filter unit operates.

5.4.1 Air Filtration and Cleaning Principles

Air filtration is the removal of particulate contaminants from the air. Air cleaning is the removal of gases or vapors from the air. The collection mechanisms for these two types of systems are very different.

Airborne contaminants can be gases, vapors, or aerosols (small solid and liquid particles). Most biological and radiological agents are aerosols, whereas most chemical warfare agents are gaseous.

Particulate Air Filters. Particulate air filters consist of fibrous materials (see Figure 5-2), which capture aerosols. Their efficiency will depend on the size of the aerosol, the type of filter, the velocity of the air, and the type of microbe. The basic principle of particulate air filtration is not to restrict the passage of particles by the gap between fibers, but by altering the airflow streamlines. The airflow will slip around the fiber, but higher density aerosols and particulates will not change direction as rapidly.

Figure 5-2 Scanning electron microscope image of a polyester-glass fiber filter

SOURCE: CDC/NIOSH PUBLICATION NO. 2003-136, *GUIDANCE FOR FILTRATION AND AIR CLEANING SYSTEMS TO PROTECT BUILDING ENVIRONMENTS FROM AIRBORNE CHEMICAL, BIOLOGICAL, OR RADIOLOGICAL ATTACKS,* APRIL 2003

Four different collection mechanisms govern particulate air filter performance: inertial impaction, interception, diffusion, and electrostatic attraction (see Figure 5-3). The first three mechanisms are the most important for mechanical filters and are influenced by particle size. Impaction occurs when a particle in an air stream passing around a filter

fiber, because of its inertia, deviates from the air stream and collides with a fiber. Interception occurs when a particle in the air stream passing around filter fibers comes in contact with a fiber because of its size. Impaction and interception are dominant for large particles (> 0.2 microns). Diffusion occurs when the random (Brownian) motion of a particle causes that particle to contact a fiber. Diffusion is the dominant collection mechanism for smaller particles (< 0.2 microns). The combined effect of these three collection mechanisms results in the classic collection efficiency curve that is shown in Figure 5-4. The fourth mechanism, electrostatic attraction, plays a minor role in mechanical filtration because, after fiber contact is made, small particles are retained on the fibers by a weak electrostatic force.

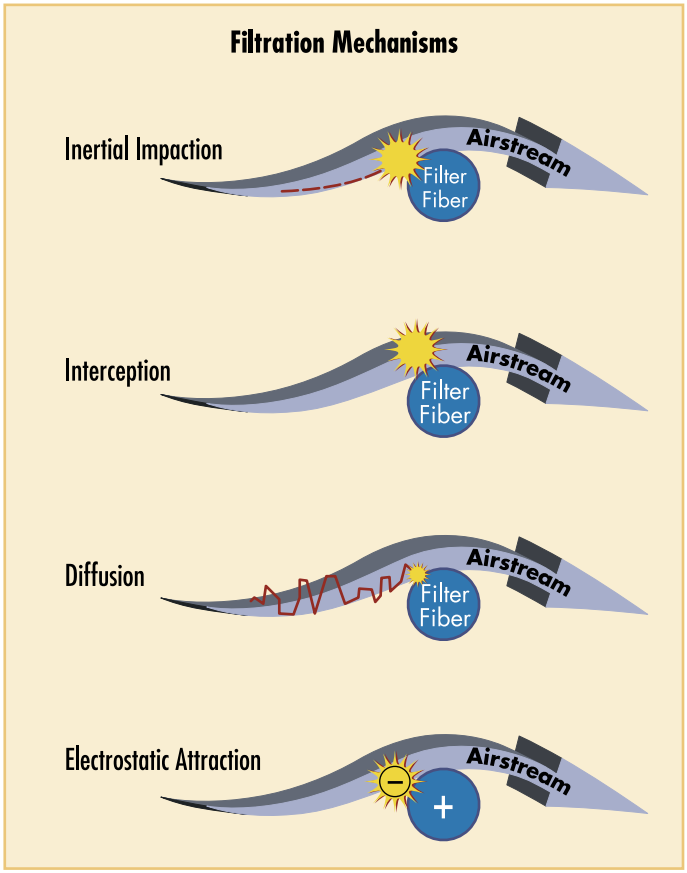


Figure 5-3 Four primary filter collection mechanisms

SOURCE: CDC/NIOSH PUBLICATION NO. 2003-136, *GUIDANCE FOR FILTRATION AND AIR CLEANING SYSTEMS TO PROTECT BUILDING ENVIRONMENTS FROM AIRBORNE CHEMICAL, BIOLOGICAL, OR RADIOLOGICAL ATTACKS,* APRIL 2003

Electrostatically enhanced filters are different from electrostatic precipitators, also known as electronic air cleaners. Electrostatic precipitators require electrical power and charged plates to attract and capture particles. In electrostatic filters, the electrostatically enhanced fibers actually attract the particles to the fibers, in addition to retaining them. Electrostatic filters use polarized fibers to increase the collection efficiency, typically have less packing density, and consequently will have a much lower pressure drop than a similar efficiency mechanical filter.

Particulate air filters are classified as mechanical filters or electrostatic filters. As a mechanical filter loads with particles over time, its collection efficiency and pressure drop typically in-

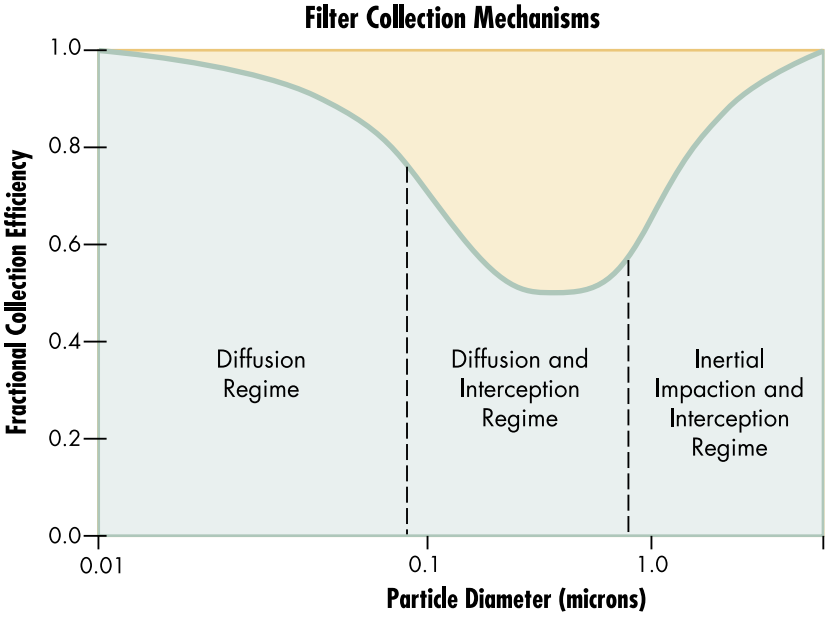


Figure 5-4 Classic collection efficiency curve

SOURCE: CDC/NIOSH PUBLICATION NO. 2003-136, *GUIDANCE FOR FILTRATION AND AIR CLEANING SYSTEMS TO PROTECT BUILDING ENVIRONMENTS FROM AIRBORNE CHEMICAL, BIOLOGICAL, OR RADIOLOGICAL ATTACKS,* APRIL 2003

crease. The pressure drop caused by particulate air filters must be taken into account in HVAC system design. Higher capacity fan units may be needed to overcome increased resistance caused by higher efficiency filters. Eventually, the increased pressure drop significantly inhibits airflow, and the filters must be replaced. For this reason, pressure drop across mechanical filters is often monitored because it indicates when to replace filters. Conversely, electrostatic filters may lose their collection efficiency over time when exposed to certain chemicals, aerosols, or high relative humidities. Pressure drop in an electrostatic filter generally increases at a slower rate than it does in a mechanical filter of similar efficiency. Thus, unlike the mechanical filter, pressure drop for the electrostatic filter is a poor indicator of the need to change filters. Periodic aerosol measurements may be appropriate to verify their performance. When selecting an HVAC filter, the differences between mechanical and electrostatic filters will have an impact on the filter's performance (collection efficiency over time), as well as on maintenance requirements (change-out schedules).

Particulate air filters are commonly rated based on their collection efficiency, pressure drop (airflow resistance), and particulate holding capacity. Two filter-rating systems are currently used in the United States, the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) Standard 52.1-1992 and ASHRAE Standard 52.2-1999. Standard 52.1 mea-

sures arrestance, dust spot efficiency, and dust holding capacity. Arrestance refers to a filter's ability to capture a mass fraction of coarse test dust and is better suited for describing low- and medium-efficiency filters. Dust spot efficiency measures a filter's ability to remove particles that tend to soil the interior of buildings. Arrestance values may be high even for low efficiency filters, and may not adequately differentiate the effectiveness of different filters for CBR protection. Dust holding capacity is a measure of the total amount of dust a filter is able to hold during a dust-loading test.

ASHRAE Standard 52.2 measures particle size efficiency (PSE). This newer standard is a more descriptive test, which quantifies filtration efficiency in different particle size ranges and is more applicable in determining a filter's effectiveness to capture a specific agent. Standard 52.2 reports the particle size efficiency results as a minimum efficiency reporting value (MERV) rating between 1 and 20. A higher MERV rating indicates a more efficient filter. The standard provides a table (see Table 5-1) showing minimum PSE for three size ranges for each of the MERV numbers 1 through 16. Thus, if the size of a contaminant is known, an appropriate filter with the desired PSE for that particular particle size can be identified.

A wide variety of particulate air filters are available to meet many specialized needs. They range from the low efficiency dust filters, such as roll-type filters used in commercial buildings, to HEPA and ultra low penetration air (ULPA) filters used in clean rooms and operating rooms (see Figure 5-5).

HEPA filters are typically rated as 99.97 percent effective in removing dust and particulate matter greater than 0.3 micron in size. The performance of high efficiency ASHRE filters is defined in terms of their total arrestance. Graphs of filter efficiency versus particle size do not constitute performance requirements and are merely a convenient way of describing performance (see Figure 5-6). Filters with the same total arrestance may have different performance curves.

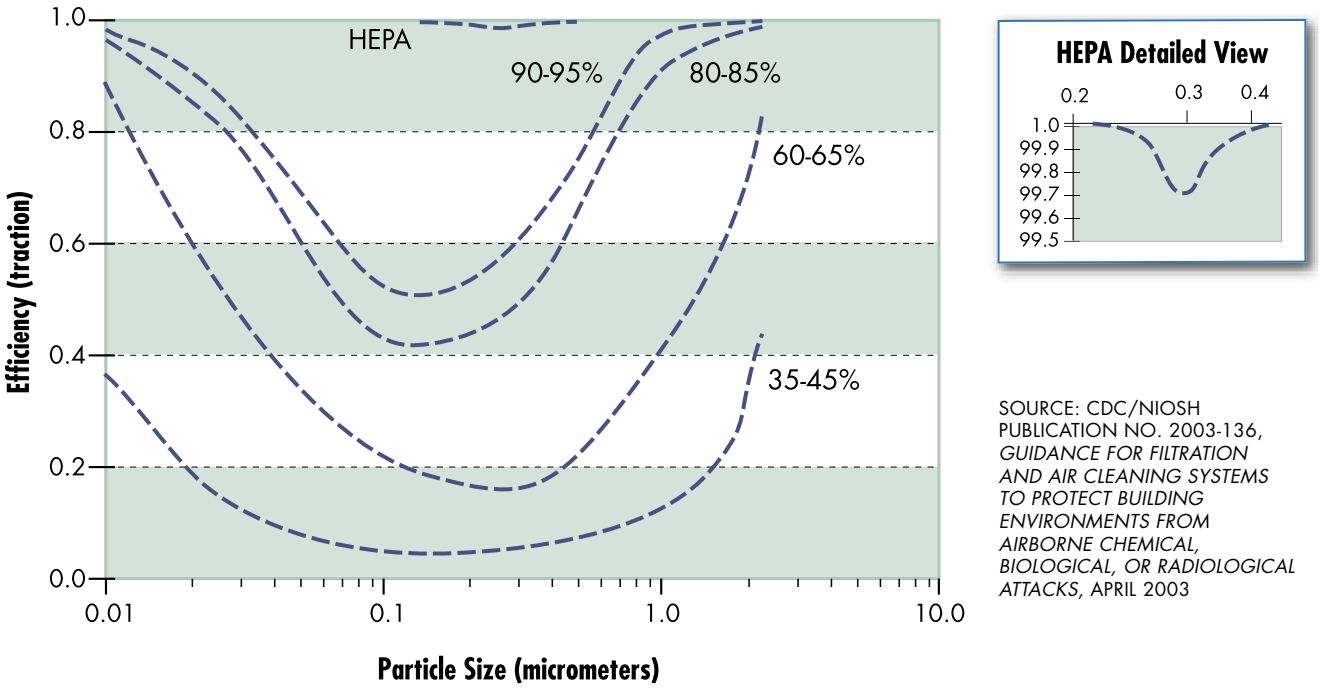
Table 5-1: Comparison of ASHRAE Standards 52.1 and 52.2

ASHRAE 52.2				ASHRAE 52.1		Particle Size Range, µm	Applications
	Particle Size Range			Test			
MERV	3 to 10 µm	1 to 3 µm	0.3 to 1 µm	Arrestance	Dust Spot		
1	< 20%	-	-	< 65%	< 20%	> 10	Residential, light, pollen, dust mites
2	< 20%	-	-	65 - 70%	< 20%		
3	< 20%	-	-	70 - 75%	< 20%		
4	< 20%	-	-	> 75%	< 20%		
5	20 - 35%	-	-	80 - 85%	< 20%	3.0 - 10	Industrial, dust, molds, spores
6	35 - 50%	-	-	> 90%	< 20%		
7	50 - 70%	-	-	> 90%	20 - 25%		
8	> 70%	-	-	> 95%	25 - 30%		
9	> 85%	< 50%	-	> 95%	40 - 45%	1.0 – 3.0	Industrial, Legionella, dust
10	> 85%	50 - 65%	-	> 95%	50 - 55%		
11	> 85%	65 - 80%	-	> 98%	60 - 65%		
12	> 90%	> 80%	-	> 98%	70 - 75%		
13	> 90%	> 90%	< 75%	> 98%	80 - 90%	0.3 – 1.0	Hospitals, Smoke removal, bacteria
14	> 90%	> 90%	75 - 85%	> 98%	90 - 95%		
15	> 90%	> 90%	85 - 95%	> 98%	~95%		
16	> 95%	> 95%	> 95%	> 98%	> 95%		
17	-	-	≥ 99.97%	-	-	< 0.3	Clean rooms, Surgery, chem-bio, viruses
18	-	-	≥ 99.99%	-	-		
19	-	-	≥ 99.999%	-	-		
20	-	-	≥ 99.9999%	-	-		

Note: This table is adapted from American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) Standard 52.2: *Method of Testing General Ventilation Air-cleaning Devices for Removal Efficiency by Particle Size,* Atlanta, GA., 1999 and Spengler, J.D., Samet, J.M., and McCarthy, J.F., *Indoor air quality Handbook,* New York, NY: McGraw-Hill, 2000.

SOURCE: TRION INCORPORATED

Figure 5-5
A bag filter and HEPA filter



SOURCE: CDC/NIOSH PUBLICATION NO. 2003-136, *GUIDANCE FOR FILTRATION AND AIR CLEANING SYSTEMS TO PROTECT BUILDING ENVIRONMENTS FROM AIRBORNE CHEMICAL, BIOLOGICAL, OR RADIOLOGICAL ATTACKS,* APRIL 2003

Figure 5-6 Comparison of filter collection efficiency based on particle size

Figure 5-7 is the characteristic performance curve of a typical HEPA filter with the design point indicated. The dip between 0.1 and 0.3 microns represents the most penetrating particle size. Many bacteria and viruses fall into this size range. Fortunately, microbes in this range are also vulnerable to ultraviolet radiation. For this reason, many health care facilities couple particulate air filters with ultraviolet germicidal irradiation (UVGI). UVGI will be discussed later in this section.

Sorbent Filters. Particulate filters are not intended to remove gases and vapors. Sorbent filters use one of two mechanisms for capturing and controlling gas-phase air contaminants, physical absorption or chemisorption.

Both mechanisms remove specific types of gas-phase contaminants in indoor air. Unlike particulate filters, sorbents cover a wide range of highly porous materials (see Figure 5-8), ranging from simple clays and carbons to complex engineered polymers. Many sorbents, with the exception of those that are chemically active, can be regenerated by application of heat or other processes.

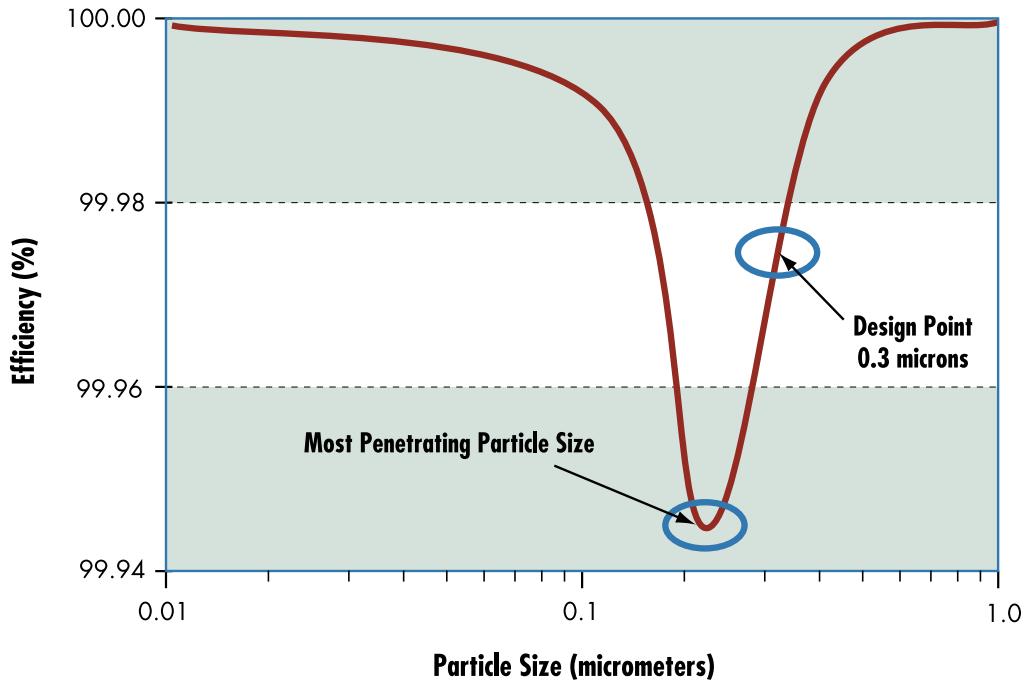


Figure 5-7 Typical performance of a HEPA 99.97%

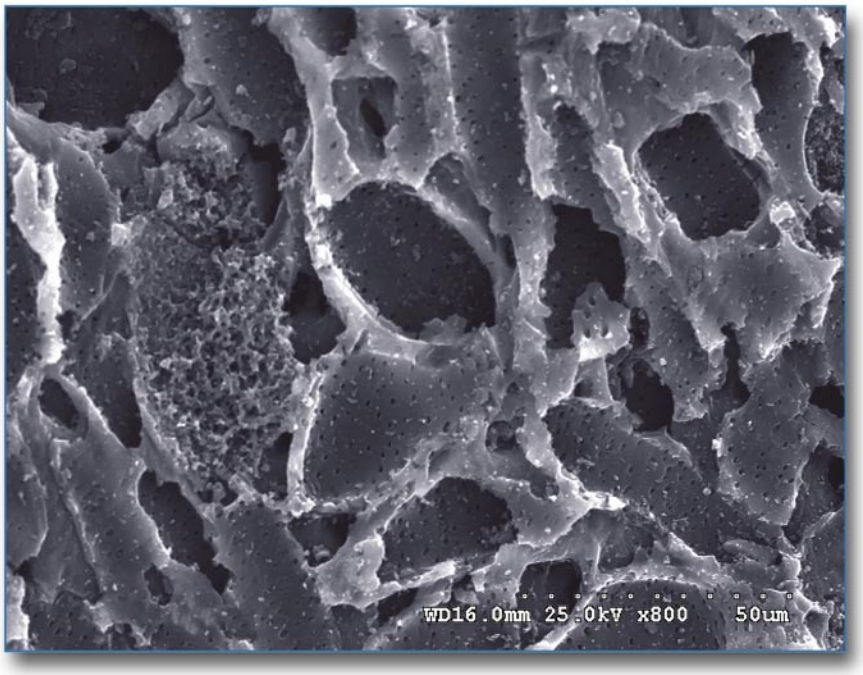


Figure 5-8 Scanning electron microscope image of activated carbon pores

SOURCE: CDC/NIOSH PUBLICATION NO. 2003-136, *GUIDANCE FOR FILTRATION AND AIR CLEANING SYSTEMS TO PROTECT BUILDING ENVIRONMENTS FROM AIRBORNE CHEMICAL, BIOLOGICAL, OR RADIOLOGICAL ATTACKS*, APRIL 2003

Understanding the precise removal mechanism for gases and vapors is often difficult due to the nature of the adsorbent and the processes involved. Although knowledge of adsorption equilibrium helps in understanding vapor protection, filter performance depends on such properties as mass transfer, chemical reaction rates, and chemical reaction capacity. Some of the most important parameters include the following:

- **Breakthrough concentration.** Breakthrough concentration is the downstream contaminant concentration, above which the sorbent is considered to be performing inadequately. Its concentration indicates the agent has broken through the sorbent, which is no longer providing maximum protection. This parameter is a function of loading history, relative humidity, and other factors.
- **Breakthrough time.** Breakthrough time is the elapsed time between initial contact of the toxic agent, at a reported challenge concentration, with the upstream surface of the sorbent bed and the time at which the breakthrough concentration occurs on the downstream side of the sorbent bed.
- **Challenge concentration.** Challenge concentration is the airborne concentration of the hazardous agent entering the sorbent.
- **Residence time.** Residence time is the length of time that the hazardous agent spends in contact with the sorbent. This term is generally used in the context of superficial residence time, which is calculated on the basis of the adsorbent bed volume and the volumetric flow rate.
- **Mass transfer zone or critical bed depth.** Mass transfer zone or critical bed depth are interchangeably used terms. They refer to the adsorbent bed depth required to reduce the chemical vapor challenge to the breakthrough concentration. When applied to the challenge chemicals that are removed by chemical reaction, mass transfer is not as precise a descriptor, but is often used in that context. The portion of the adsorbent bed not included in the mass transfer zone is often termed the capacity zone.

Choosing the appropriate sorbent or sorbents for an airborne contaminant is a complex decision that involves many factors. The installation of sorbent filters for the removal of gaseous contaminants from a building's air is a less common practice than the installation of particulate filtration. Sorbents have different affinities, removal efficiencies, and saturation points for each chemical agent. The EPA states that a well-designed adsorption system should have removal efficiencies ranging from 95 percent to 98 percent for industrial contaminant concentrations in the range of 500 to 2,000 ppm; higher collection efficiencies are needed for high toxicity CBR agents. Sorbent physicochemical properties (e.g., pore size and shape, surface area, pore volume, and chemical inertness) all influence the ability of a sorbent to collect gases and vapors. Sorbent manufacturers have published extensive information regarding the proper use of gas-phase sorbents, based upon contaminants and conditions. The air contaminant's concentration, molecular weight, molecule size, and temperature are all important.

Sorbents are rated in terms of adsorption capacity (i.e., the amount of the chemical that can be captured) for many chemicals. This capacity rises as concentration increases and temperature decreases. The rate of adsorption (i.e., the efficiency) falls as the amount of contaminant captured grows. Adsorption capacity information (available from manufacturers, scientific literature, and the Internet) allows users to predict the service life of a sorbent bed.

Gases are removed in the sorbent bed's mass transfer zone. As the sorbent bed removes gases and vapors, the leading edge of this zone is saturated with the contaminant, while the trailing edge is clean, as dictated by the adsorption capacity, exposure history, and filtration dynamics. Significant quantities of the air contaminant may pass through the sorbent bed if breakthrough occurs. Breakthrough may be avoided by selecting the appropriate quantity of sorbent and performing regular maintenance.

Activated carbon (see Figure 5-9) is the most common sorbent. The huge surface area of activated carbon gives it countless

bonding sites. Typically, the pores in highly activated carbon have a total surface area of over 1,000 square meters per gram. Common substances used as a base material for producing carbon are wood, coal, and coconut shell. Impregnating carbon with special chemicals can enhance the absorption of specific gases. A broad-based chemical addition typically used is copper-silver-zinc-molybdenum-triethylenediamine (ASZM-TEDA). Both the DOS and DoD currently recommend ASZM-TEDA sorbent for collecting classical chemical warfare agents.

Figure 5-9 Charcoal filter beds

SOURCE: FLANDERS CORPORATION

Sorbent filters should be located downstream of the particulate filters. This arrangement allows the sorbent to collect vapors generated from liquid aerosols collected on the particulate filter and reduces the amount of particulate reaching the sorbent. Gas-phase contaminant removal can potentially be a challenging and costly undertaking, and different factors should be addressed.

All sorbents have limited adsorption capacities and require scheduled maintenance. The effective residual capacity of an activated carbon sorbent bed is not easily determined while in use, and saturated sorbents can re-emit collected contaminants. Sorbent life depends upon bed volume or mass, along with shape, which influences airflow through the sorbent bed. Chemical agent concentrations and other gases (including humidity) affect the bed capacity. Because of differences in affinities, it is possible that one chemical may displace another chemical, which can be readsorbed downstream or forced out of the bed. Most sorbents come in pellet form, which makes it possible to mix them. Mixed- and/or layered-sorbent beds permit effective removal of a broader range of contaminants than possible with a single sorbent. Many sorbents can be regenerated, and it is important to closely follow manufacturers' guidance to ensure that sorbents are replaced or regenerated in a safe and effective manner.

Some chemically active sorbents are impregnated with strong oxidizers, such as potassium permanganate. The adsorbent part

of the bed captures the target gas and gives the oxidizer time to react and destroy other agents. Chemically active sorbents should not be reused because the oxidizer is consumed over time. If the adsorbent bed is exposed to high concentrations of vapors, exothermic adsorption could lead to a large temperature rise and filter bed ignition. This risk can be exacerbated by the nature of impregnation materials. It is well known that lead and other metals can significantly lower the spontaneous ignition temperature of a carbon filter bed. Sorbent bed fires are extremely dangerous, and steps should be taken to avoid this hazard. These systems should be located away from heat sources and automatic shut-off and warning capabilities should be included in the system.

Air Filtration Considerations. In addition to proper filter or sorbent selection, the following must be considered when installing or upgrading filtration systems:

- **Filter bypass** is a common problem found in many HVAC filtration systems. It occurs when air, rather than moving through the filter, goes around it, decreasing collection efficiency and defeating the intended purpose of the filtration system. Filter bypass is often caused by poorly fitting filters, poor sealing of filters in their framing systems, missing filter panels, or leaks and openings in the air handling unit downstream of the filter bank and upstream of the blower. Simply improving filter efficiency without addressing filter bypass provides little, if any, improvement to system efficiency.

- **Cost** is another issue affected by HVAC filtration systems. Both first and life-cycle costs should be considered (e.g., initial installation, replacement, operating, maintenance, etc.). Not only are higher-efficiency filters and sorbent filters more expensive than the filters traditionally used in HVAC systems, but fan units may also need to be upgraded to handle the increased pressure drop associated with the upgraded filtration systems. Although improved filtration will normally come at a higher cost, many of these costs can be partially offset by the beneficial effects, such as cleaner (and

more efficient) HVAC components and improved indoor environmental quality.

- **Filtration and air-cleaning** affect only the air that passes through the filtration and air-cleaning device, whether it is outdoor air, recirculated air, or a mixture of the two. Building envelopes in residential and commercial buildings are, in general, quite leaky, and significant quantities of air can infiltrate the building envelope with minimal filtration. Field studies have shown that, unless specific measures are taken to reduce infiltration, as much air may enter a building through infiltration as through the mechanical ventilation system. Therefore, building managers should not expect filtration alone to protect a building from outdoor releases, particularly for systems in which no make-up air or inadequate over-pressure is present. Instead, filtration in combination with other steps, such as building pressurization and tightening the building envelope, should be considered to increase the likelihood that the air entering the building actually passes through the filtration and air-cleaning systems.

Ultraviolet Germicidal Irradiation (UVGI). UVGI has long been used in laboratories and health care facilities. Ultraviolet radiation in the range of 2,250-3,020 Angstroms is lethal to micro-organisms. All viruses and almost all bacteria (excluding spores) are vulnerable to moderate levels of UVGI exposure. Spores, which are larger and more resistant to UVGI than most bacteria, can be effectively removed through high efficiency air filtration. For these reasons, today most UGVI systems are installed in conjunction with high efficiency filtration systems in many health care facilities.

Figure 5-10
UVGI array used for air disinfection with reflective surfaces

SOURCE: LUMALIER INCORPORATED

Ultraviolet (UV) lamps resemble ordinary fluorescent lamps (see Figure 5-10), but are specially designed to emit germicidal UV and include a glass envelope to filter out harmful, ozone forming radiation. The lamps are available in a variety of sizes and shapes and must be mounted in special housings and located so that people are not exposed to direct irradiation. Newer more advanced compact UV tubes provide higher output in the UV-C bandwidth

(253.7 nanometer wavelength) and increased reliability. UVGI safety measures, such as duct access interlocks that turn off the lamps when the duct housing is opened, should be used.

Manufacturers offer UVGI systems suitable for in-duct or large plenum installations. Retrofitting UVGI systems can also be relatively simple if sufficient space is available. There are UV lamps that can be mounted externally in ductwork and pressure losses across such lamps are often negligible. When installing a UVGI system, attention must be paid to maintaining design air velocity and temperature of the UV lamps. Cooling the plasma inside a UV lamp can significantly affect its UV output. Polished aluminum reflective panels can also be used to increase the intensity of a UVGI field in an enclosed duct or chamber. The design velocity for a typical UVGI unit is similar to that of particulate filters (about 400 feet per minute). It is very important to properly design and install UVGI systems in order to obtain the desired effects. Improper systems may provide a false sense of protection. For a discussion of the factors that should be considered when designing and sizing a UVGI system, additional information can be found in W. J. Kowalski, *Immune Building Systems Technology* (McGraw Hill, 2003).

A design utilizing a combination of filtration and UVGI can be very effective against biological agents. Smaller microbes, which are difficult to filter out, tend to be more susceptible to UVGI; while larger microbes, such as spores, which are more resistant to UVGI, tend to be easier to filter out.

5.4.2 Applying External Filtration

Applying external filtration to a building requires modifications to the building's HVAC system and electrical system, and it also usually requires minor architectural changes to reduce air leakage from the selected protective envelope. These changes are necessary to ensure that, when the protective system is in operation, all outside air enters the building through the filters. The air exchange that normally occurs due to wind, chimney effect, and operation of fans must be reduced to zero. This is

achieved mainly by introducing filtered air at a rate sufficient to produce an overpressure in the building and create an outward flow through all cracks, pores, seams, and other openings in the building envelope. For standby systems, dampers are normally required to tighten the envelope in transitioning to the protective mode. The level of overpressure required varies with weather conditions and height of the building.

The capacity of filtration units needed for protection is determined by the leakage characteristics and size of the building. The cost of installing a high efficiency filtration system varies directly with the leakage rate; higher leakage rate equals higher costs, and the need for additional heating and cooling capacity for the filtered air.

Filtration system capacity must be matched to the leakage of the building to achieve maximum protection. Fan-pressurization tests are usually performed on buildings to determine their normalized leakage rates. Nominal data on the leakage rates of various types of buildings are available in the U.S. Army Corps of Engineers Engineering Technical Letter (ETL) 1110-3-498, *Design of Collective Protection Shelters to Resist Chemical, Biological, and Radiological (CBR) Agents*, (February 24, 1999) and can be used to estimate the leakage rate of a building.

For a terrorist threat, the U.S. Army Corps of Engineers recommends a minimum HVAC CBR filtration system overpressure goal of 5 Pa (0.02 inch water gauge [wg]). This overpressure corresponds to an impact pressure normal to a wall from a 12-km/hr (7-mph) wind. After installation of an overpressure system (see Figure 5-11), it is possible that a pressure greater than 5 Pa (0.02 inch wg) will be achieved. A higher pressure provides a higher factor of safety and should not be intentionally lowered.

Figure 5-11
A military FFA 580 air filtration system containing both a HEPA filter and an ASZM-TEDA carbon adsorber as part of an overpressure system

Currently, there are no criteria or guidance for the performance of filtration systems designed for protecting building occupants against CBR agents. The U.S. military has issued very conservative criteria in the ETL referenced above, which is not based on analytical or empirical research. Recent research in the field suggests significant levels of protection can be achieved with medium to high efficiency filters (see Figure 5-12), especially when used in combination with UVGI.[1] In a recent simulation in the Architectural Engineering Department of Pennsylvania State University, various combinations of MERV and UVGI Rating Values (URV) systems were modeled for a 20-story building subject to releases of anthrax, smallpox, and botulinum. No significant benefits were shown for filtration/URV levels beyond MERV 13/URV 13.[2]

SOURCE: TRION INCORPORATED

Figure 5-12
A commercial air filtration unit

[1] W. J. Kowalski, W. P. Bahnfleth, and T. S. Whittam, *Filtration or Airborne Microorganisms: Modeling and Prediction* http://www.engr.psu.edu/ae/wjk/fom.html.

[2] W. J. Kowalski, *Defending Buildings Against Bioterrorism, Engineering Systems*, September 30, 2002 http://www.esmagazine.com/CDA/ArticleInformation/features/BNP_Features_Item/0,2503,84858,00.html.

Various types of high efficiency filter systems, both commercial and military, have been used for building protection. The current DoD recommended carbon for filtering a broad range of toxic chemical vapors and gases is ASZM-TEDA carbon per military specification EA-C-1704A maintained by the U.S. Army Edgewood Chemical Biological Center, Aberdeen Proving Ground, MD.

High efficiency air filtration can be most economically applied by integrating it into the HVAC system in the design of new construction. Application of filtration systems in retrofit involves greater costs.

Filter systems can be applied to protect either all or part of a building. At least part of the building is always excluded from the envelope being protected (i.e., areas having or requiring high rates of air exchange with the outdoors, such as mechanical rooms containing boilers or generators and receiving areas). Mechanical rooms that contain air handling units must be included within the protective envelope. Filter systems may be designed to operate on either a continuous duty cycle or on standby. The assumption with the latter is that they will be turned on when there is greater likelihood of an airborne hazard occurring.

The disadvantage of external air filtration is its high costs for hardware, installation, operation, and maintenance. The main cost component of operating the filter units is the electrical power required to force air through the filters. The airflow resistance of HEPA filters is typically about 1 inch wg, and this resistance increases steadily as the filter loads with dust or other fine particles in service. For high efficiency carbon filters, the pressure drop may range from about 1 to 4 inch wg. Maintenance costs involve periodic filter replacement. Particulate filter change-out is generally based on the airflow resistance rising to unacceptable levels.

There is no simple means for determining how much capacity remains in a carbon filter. Because the service life varies with the environment in which it operates, it can be replaced according

to time in service using a conservative estimate, or its remaining capacity can be measured by the use of test canisters. With the reserve capacity normally designed into carbon filters, a filter can maintain efficiency greater than 99.999 percent for about 3 years of continuous use with ASZM-TEDA carbon, depending upon the quality of air in the environment it operates.

5.4.3 Applying Internal Filtration (Recirculation Filter Units)

Internal filtration can be applied much more easily, in many cases without any modifications to the building or installation costs; however, it provides a much lower level of protection against an external release than does high efficiency external filtration. One advantage of internal filtration is in purging contaminants from a building following an internal release. Also referred to as recirculation filtering, the protection it provides against an external release is dependent upon the rate at which air in the building envelope is exchanged with outdoor air. The tighter the building, the greater the protection achieved with internal filtration.

Recirculation filter units can be employed to increase protection achieved by sheltering in place. This involves the use of free-standing units referred to as indoor air purifiers or indoor air quality filter units. Many of these contain filters for removal of both aerosols and chemicals vapors. These typically have high efficiency filters for the removing aerosols (HEPA filters); however, the chemical filters are of relatively low efficiency, typically ranging from less than 50 percent to as high as 99 percent. Because of the relatively high efficiency of the HEPA filter versus the carbon filter, typically available in recirculation filter units, these units can provide a higher level of protection against an aerosol than against chemical vapors. The carbon filters also do not typically contain the impregnated carbon capable of removing chemicals of high vapor pressure. Manufacturers provide guidance on the size of room a single unit will accommodate. Because these filters are designed mainly for filtering pollen and dust and removing odors, there are no claims or guidance as to their protective capability.

Internal filtration can also be applied by simply installing higher efficiency particulate filters and/or carbon filters in place of standard dust filters in air handling units. Air handling units are not designed, however, to accommodate the large increase in airflow resistance a high efficiency filter or carbon filter would add. The capability of the existing air handling unit must be examined before such installations are attempted. In typical air handling units, dust filter slots allow relatively high bypass around the filter media, reducing overall efficiency of the HEPA filters. Internal filtration protection against biological agents can also be enhanced through the installation of an UVGI system as discussed earlier.

5.4.4 Radiological Hazards

Radiological hazards can be divided into three general forms: alpha, beta, and gamma radiation, which are emitted by radioisotopes that may occur as an aerosol, be carried on particulate matter, or occur in a gaseous state. Alpha particles, consisting of two neutrons and two protons, are the least penetrating and the most ionizing form of radiation. They are emitted from the nucleus of radioactive atoms and transfer their energy at very short distances. Alpha particles are readily shielded by paper or skin and are most dangerous when inhaled and deposited in the respiratory tract. Beta particles are negatively charged particles emitted from the nucleus of radioactive atoms. Beta particles are more penetrating than alpha particles, presenting an internal exposure hazard. They can penetrate the skin and cause burns. If they contact a high density material, they may generate x-rays also known as "Bremmstrahlung radiation." Gamma particles are emitted from the nucleus of an atom during radioactive decay. Gamma radiation can cause ionization in materials and biological damage to human tissues, presenting an external radiation hazard.

There are three primary scenarios in which radioactive materials could be dispersed by a terrorist: use of conventional explosives or other means to spread radioactive materials (a dirty bomb), attack on a fixed nuclear facility, and use of a nuclear weapon. In any of these events, filtration and air cleaning devices would be ineffec-

tive at stopping the radiation itself; however, they would be useful in collecting the material from which the radiation is emitted. Micrometer-sized aerosols from a radiological event are effectively removed from air streams by HEPA filters. This collection could prevent distribution throughout a building; however, decontamination of the HVAC system would be required.

5.5 EXHAUSTING AND PURGING

Turning on building ventilation fans and smoke-purge fans is a protective action for purging airborne hazards from the building and reducing occupant exposure, but it is mainly useful when the source of the hazard is indoors.

Purging must be carefully applied with regard to the location of the source and the time of the release. It must be clear that the source of the hazard is inside the building and, if not, purging should not be attempted. If the hazardous material has been identified before release or immediately upon release, purging should not be employed, because it may spread the hazardous material throughout the building or HVAC zone. In this case, all air handling units should be turned off to isolate the hazard while evacuating or temporarily sheltering in place.

Additionally, the ventilation system and smoke purge fans can be used to purge the building following an external release after the hazard outdoors has dissipated, and it has been confirmed that the agent is no longer present near the building.

5.6 CBR DETECTION

Most strategies for protecting people from airborne hazards require a means of detection (i.e., determining that a hazard exists). Although effective and inexpensive devices are widely available to detect, for example, smoke and carbon monoxide, there are no detectors that can rapidly alert occupants to a broad range of chemical and biological hazards.

Chemical detection technology has improved vastly since Operation Desert Storm, where many military detection systems experienced high false alarm rates, but biological detection technology has not matured as fast. Biological signatures are not as distinctive as chemical signatures and can take 30 minutes or more to detect. Biological detection systems are expensive and generally require trained specialists to operate. Current chemical detectors work in approximately 10 seconds; however, the current state of biological and chemical detection is limited to detecting specific agents. There currently is no all-inclusive detection system available. Wide varieties of efficient radiological detectors have been developed for the nuclear industry and are commercially available. The NBC Products and Services Handbook, which was discussed in Section 5.3, contains a catalogue of CBR detection equipment. Additionally, the NIJ has reviewed chemical and biological detection devices in NIJ Guide 100-00: *Guide for the selection of Chemical Agent and Toxic Industrial Material Detection Equipment for Emergency First Responders*, June 2000; and NIJ Guide 101-00: *An Introduction to Biological Agent Detection Equipment for Emergency First Responders*, December 2001.

Chemical Detectors. Driven largely by a desire to protect workers from toxic vapors in industrial environments, considerable information is known on the toxicity of chemical warfare agents, which often have dual uses in industry. A variety of detection technologies exist, ranging from inexpensive manual point detection devices (e.g., paper strips and calorimetric tubes) utilizing basic chemical reactions to trigger color changes, to sophisticated detection systems utilizing advanced technologies.

Chemical agents do not possess universal properties that permit detection by any single method. Therefore, most chemical detectors are designed to detect specific agents or a group of related agents. Most broad range detection systems actually combine several different sensors utilizing different technologies and can be very expensive and complex. Nevertheless, today there are numerous commercially available chemical detectors. The most capable detectors utilize ion mobility spectrometry (IMS), surface

acoustic wave (SAW), or gas chromatograph/mass spectrometer (GC/MS) technologies to detect chemical agents and toxic industrial materials (TIMs).

IMS detectors draw gaseous samples with an air pump into a reaction chamber where a radioactive source ionizes the sample. The ionized sample is then injected into a closed drift tube through a shutter that isolates the sample from atmospheric air. The drift tube has a weak electric field that draws the sample toward an ion detector. An electrical charge is generated upon impact with the ion detector. The time it takes for species to traverse the field and the intensity of the charge generated are used as a means of identifying the chemical agent.

SAW detectors consist of piezoelectric crystals coated with a film specially designed to absorb chemical agents from the air. They typically use multiple piezoelectric crystals coated with different polymeric films, each designed to absorb a particular class of volatile compound. The piezoelectric crystals absorb chemical vapors, which cause the resonant frequency of the crystal to change. By monitoring the resonant frequency of the different piezoelectric crystals, a response pattern of the system for a particular vapor is generated. Many SAW devices use pre-concentration tubes to reduce environmental interferences and increase detector sensitivity.

A GC uses inert gas to transport a sample of air through a long chromatographic column. Each molecule sticks to the column with a different amount of force and does not travel down the column at the same speed as the carrier gas. This causes the chemical agents and interferants to come out of the end of the column at different times (called the retention time). Because the retention time is known for the chemical agents, the signal from an associated detector is only observed for a short period starting before and ending just after the retention time of the chemical agent, eliminating false alarms from similar compounds that have different retention times. Using a pre-concentrator specific to the analyte can also reduce false alarms caused by interferants.

Mass spectrometry is a technique that can positively identify a chemical agent at very low concentrations. In this technique, a volatilized sample is ionized, typically by an electron beam, which also causes the molecule to fragment into smaller ionized pieces. The ionized molecules and fragments are then passed into a mass analyzer that uses electric fields to separate the ions according to the ratio of their mass divided by their electric charge. The analyzer allows only ions of the same mass over charge ratio to impinge upon the detector. By scanning the electric potentials in the mass analyzer, all the different mass/charge ions can be detected. The result is a mass spectrum that shows the relative amount and the mass of each fragment, and the unfragmented parent molecule. Because each molecule forms a unique set of fragments, mass spectroscopy provides positive identification. To simplify interpretation of the mass spectrum, it is best to introduce only one compound at a time. This is often achieved by using a gas chromatograph to separate the components in the sample. The end of the gas chromatography column is connected directly to the inlet of the mass spectrometer. When used in combination, a GC/MS is one of the most sensitive and discerning tools for identifying chemical and biological compounds; however, it requires significant skill to operate and interpret the results.

Figure 5-13
An IMS chemical detector designed for installation in HVAC systems
SOURCE: SMITHS DETECTION

Today, there are commercially available IMS detection systems that will detect most chemical agents and many TIMs (see Figure 5-13). They are suitable for integration into a building's HVAC system, can interface with HVAC control systems, have reasonable maintenance requirements (every 3 months), low false alarm rates, and can be programmed to detect specific chemical agents.

Biological Detectors. The current state of biological detection technology is very different from that of chemical agent detection technology. In general, most biological detection systems are currently in the research and early development stages. There are some commercially available devices that have limited utility (responding only to a small number of agents) and are generally

high cost items. Because commercially available biological warfare (BW) detection systems and/or components exhibit limited utility in detecting and identifying BW agents and are also costly, it is strongly recommended that purchasers be very careful when considering any device that claims to detect BW agents.

One reason for the lack of available biological detection equipment is that detection of biological agents requires extremely high sensitivity (because of the very low effective dose needed to cause infection and spread the disease) and an unusually high degree of selectivity (because of the large and diverse biological background in the environment). Another reason for the lack of biological detection equipment is that biological agents, compared to chemical agents, are very complex systems of molecules, which makes them much more difficult to identify. For example, ionization/ion mobility spectrometry, an excellent system for collection, detection, and identification of chemical agents, cannot detect or discriminate biological agents in their current forms. In fact, the need for high efficiency collection and concentration of the sample, high sensitivities, and high selectivities make almost all chemical detectors in their current form unusable for biological agent detection.

Because of the need for high selectivity and sensitivity, biological detection systems are necessarily complex and expensive devices. In general, biological sensors can detect one specific agent, and can usually only be used once. Some biological sensors are in current use in the food industry. The U.S. military is developing several detection systems that show some promise. However, these systems are very complicated, require highly trained operators, extensive maintenance, and are extremely expensive to purchase and operate.

For all these reasons, biological detection technologies will not be discussed herein. One alternative could be to use particle detectors. In theory, biological agents could be identified by a particle detector based on their characteristic size range. In fact, most biological detectors use trigger or cue technology to identify a change in the particulate background at the sensor to trigger the additional components of the detection system into

operation. However, in practice, there are numerous problems when attempting to identify biological agents with particle detectors. Particulates in the atmosphere originate from a number of sources. Dust, dirt, pollen, and fog are all examples of naturally occurring particulates found in the air. Manmade particulates such as engine exhaust, smoke, and industrial effluents (smokestacks) also contribute significantly to the environmental particulate background. The particulate background can change on a minute-by-minute basis, depending on the meteorological conditions at the time. For example, the particulate background next to a road will change dramatically, depending on whether there is traffic on the road disturbing the dust, or if the road is empty. Likewise, if there is little wind, not many particulates are carried into the atmosphere; however, when the wind begins to blow, it can carry many particulates from the immediate vicinity, as well as from remote locations. The challenge for a biological detection system is to be able to discriminate between all of the naturally occurring particulates and the biological agent particulates. Thus, identification of biological agents with particle detectors alone may be extremely difficult.

5.7 INDICATIONS OF CBR CONTAMINATION

Most hazardous chemicals have warning properties that provide a practical means for detecting a hazard and initiating protective actions. Such warning properties make chemicals perceptible; for example, vapors or gases can be perceived by the human senses (i.e., smell, sight, taste, or irritation of the eyes, skin, or respiratory tract) before serious effects occur. The distinction between perceptible and imperceptible agents is not an exact one. The concentrations at which a person can detect an odor vary from person to person, and these thresholds also vary relative to the concentration that can produce immediate, injurious effects.

Most of the industrial chemicals and chemical-warfare agents are readily detectable by smell. Soldiers in World Wars I and II were taught to identify, by smell, such agents as mustard, phosgene, and chlorine, and this detection method proved effective for

determining when to put on and take off a gas mask. An exception is the chemical-warfare agent sarin, which is odorless and colorless in its pure form and, therefore, imperceptible. Among the most common toxic industrial chemicals, carbon monoxide is one of the few that is imperceptible.

Biological agents are also imperceptible and there are no detection devices that can determine their presence in the air in real time. Current methods for detecting bacterial spores, such as anthrax, require a trained operator and expensive equipment. It is not currently possible to base protective responses to biological agents on detection.

Researchers are working on a prototype device to automatically and continuously monitor the air for the presence of bacterial spores. The device would continuously sample the air and use microwaves to trigger a chemical reaction, the intensity of which would correspond to the concentration of bacterial spores in the sample. If an increase in spore concentration is detected, an alarm similar to a smoke detector would sound and a technician would respond and use traditional sampling and analysis to confirm the presence of anthrax spores. Researchers hope the device response time will be fast enough to help prevent widespread contamination.

In the absence of a warning property, people can be alerted to some airborne hazards by observing symptoms or effects in others. This provides a practical means for initiating protective actions, because the susceptibility to hazardous materials varies from person to person. The concentrations of airborne materials may also vary substantially within a given building or room, producing a hazard that may be greater to some occupants than to others.

Other warning signs of a hazard may involve seeing and hearing something out of the ordinary, such as the hiss of a rapid release from a pressurized cylinder. Awareness to warning properties, signs, and symptoms in other people is the basis of a protective action plan. Such a plan should apply four possible protective actions: sheltering in place, using protective masks, evacuating, and purging, as already discussed in this chapter.

For protection against imperceptible agents, the only practical protective measures are those that are continuously in place, such as filtering all air brought into the building on a continuous basis and using automatic, real-time sensors that are capable of detecting the imperceptible agents.

Chemical, biological, and radiological materials, as well as industrial agents, may travel in the air as a gas or on surfaces we physically contact. Dispersion methods may be as simple as placing a container in a heavily used area, opening a container, or using conventional (garden)/commercial spray devices, or as elaborate as detonating an aerosol.

Chemical incidents are characterized by the rapid onset (minutes to hours) of medical symptoms and easily observed indicators (e.g., colored residue, dead foliage, pungent odor, and dead animals, birds, fish, or insects; see Table 5-2 and Figure 5-14).

In the case of a biological incident, the onset of symptoms takes days to weeks and, typically, there will be no characteristic indicators (see Table 5-3 and Figure 5-15). Because of the delayed onset of symptoms in a biological incident, the area affected may be greater due to the migration of infected individuals.

In the case of a radiological incident, the onset of symptoms also takes days to weeks to occur and typically there will be no characteristic indicators (see Table 5-4 and Figure 5-16). Radiological materials are not recognizable by the senses because they are colorless and odorless.

Specialized equipment is required to determine the size of the affected area and if the level of radioactivity presents an immediate or long-term health hazard. Because of the delayed onset of symptoms in a radiological incident, the affected area may be greater due to the migration of contaminated individuals.

Table 5-2: Indicators of a Possible Chemical Incident

Dead animals, birds, fish	Not just an occasional roadkill, but numerous animals (wild and domestic, small and large), birds, and fish in the same area.
Lack of insect life	If normal insect activity (ground, air, and/or water) is missing, check the ground/water surface/ shore line for dead insects. If near water, check for dead fish/aquatic birds.
Physical symptoms	Numerous individuals experiencing unexplained water-like blisters, wheals (like bee stings), pinpointed pupils, choking, respiratory ailments, and/or rashes.
Mass casualties	Numerous individuals exhibiting unexplained serious health problems ranging from nausea to disorientation to difficulty in breathing to convulsions to death.
Definite pattern of casualties	Casualties distributed in a pattern that may be associated with possible agent dissemination methods.
Illness associated with confined geographic area	Lower attack rates for people working indoors than those working outdoors, and vice versa.
Unusual liquid droplets	Numerous surfaces exhibit oily droplets/film; numerous water surfaces have an oily film. (No recent rain.)
Areas that look different in appearance	Not just a patch of dead weeds, but trees, shrubs, bushes, food crops, and/or lawns that are dead, discolored, or withered. (No current drought.)
Unexplained odors	**Smells may range from fruity to flowery to sharp/pungent to garlic/horseradish-like to bitter almonds/peach kernels to new mown hay. It is important to note that the particular odor is completely out of character with its surroundings.**
Low-lying clouds	Low-lying cloud/fog-like condition that is not explained by its surroundings.
Unusual metal debris	Unexplained bomb/munitions-like material, especially if it contains a liquid. (No recent rain.)

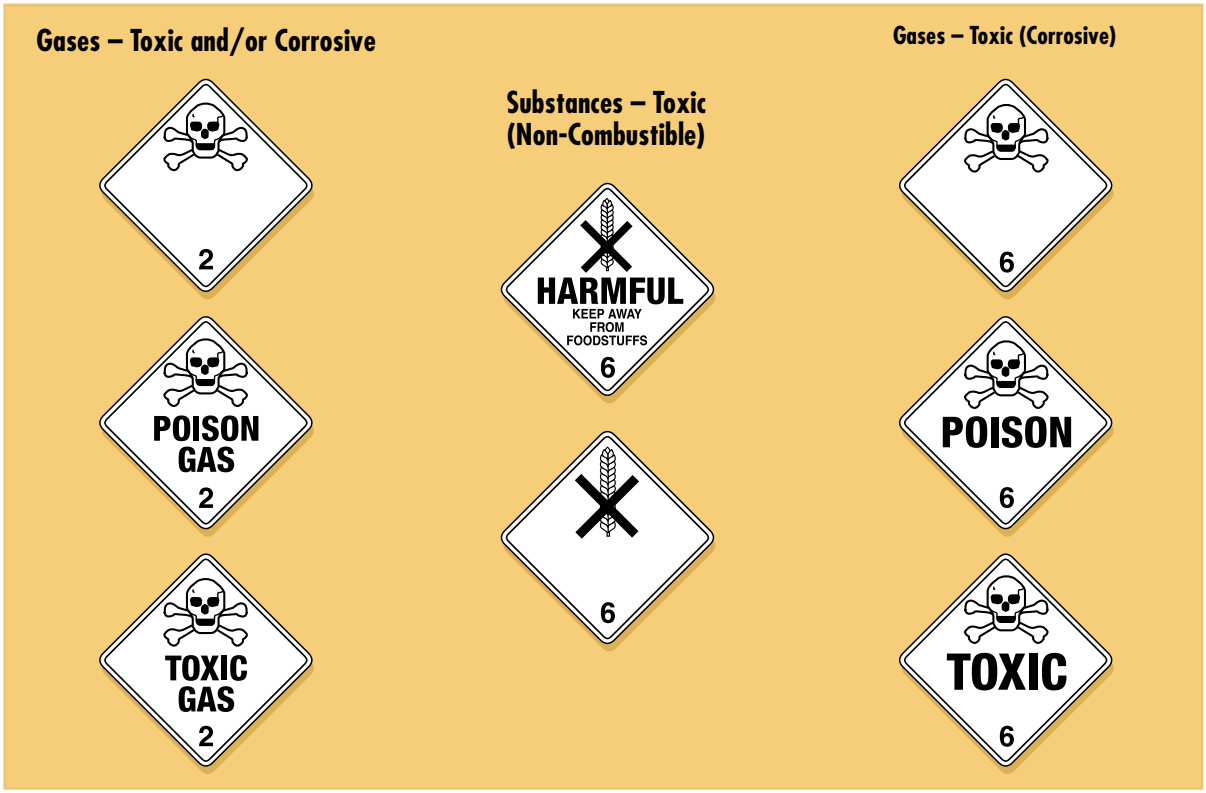


Figure 5-14 Placards associated with chemical incidents

Table 5-3: Indicators of a Possible Biological Incident

Unusual numbers of sick or dying people or animals	Any number of symptoms may occur. As a first responder, strong consideration should be given to calling local hospitals to see if additional casualities with similar symptoms have been observed. Casualties may occur hours to days or weeks after an incident has occurred. The time required before symptoms are observed is dependent on the biological agent used and the dose received. Additional symptoms likely to occur include unexplained gastrointestinal illnesses and upper respiratory problems similar to flu/colds.
Unscheduled and unusual spray being disseminated	Especially if outdoors during periods of darkness.
Abandoned spray devices	Devices will have no distinct odors.

Figure 5-15 Placards associated with biological incidents

Table 5-4: Indicators of a Possible Radiological Incident

Unusual numbers of sick or dying people or animals	As a first responder, strong consideration should be given to calling local hospitals to see if additional casualties with similar symptoms have been observed. Casualties may occur hours to days or weeks after an incident has occurred. The time required before symptoms are observed is dependent on the radioactive material used and the dose received. Additional symptoms likely to occur include skin reddening and, in severe cases, vomiting.
Unusual metal debris	Unexplained bomb/munitions-like material.
Radiation symbols	Containers may display a radiation symbol.
Heat emitting material	Material that seems to emit heat without any sign of an external heating source.
Glowing material/particles	If the material is strongly radioactive, it may emit a radioluminescence.

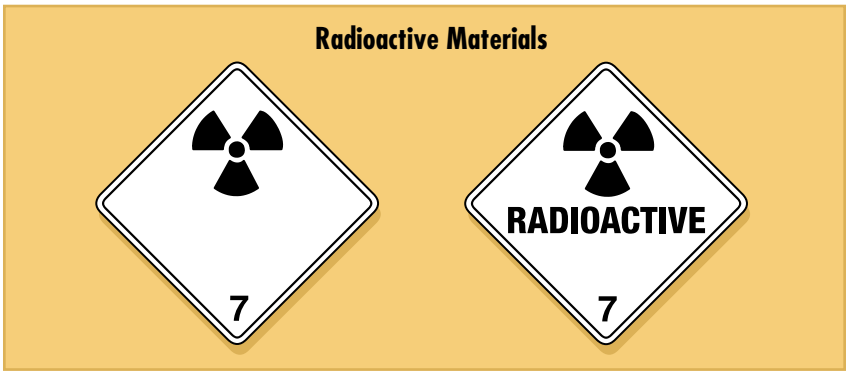


Figure 5-16 Placards associated with radiological incidents