This chapter is based on guidance from the Centers for Disease Control and Protection (CDC)/National Institute for Occupational Safety and Health (NIOSH) and the DoD and presents protective measures and actions to safeguard the occupants of a school 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 Chapters 3 and 6, and Appendix C contains information on chemical and biological agent characteristics. FEMA 426 *Reference Manual to Mitigate Potential Terrorist Attacks Against Buildings* contains detailed information on CBR threats.

Although the likelihood of a direct attack against a school is very low, recent terrorist events have increased interest in the vulnerability of all types 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.

Airborne hazardous 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.

[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.

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. Filtering and Pressurization
5. Exhausting and Purging

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 school safety emergency plan specific to each school, as well as training and familiarization for occupants, is required (see Sections 3.11 and 3.12). 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, but 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 to the building; 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 structure will be carried downwind.

5.2 SHELTERING IN PLACE

Typically, buildings offer little protection to occupants from airborne hazards outside the structure because outdoor air must be continuously introduced to provide a comfortable, healthy indoor environment. However, a school 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. Additional information can be found in Section 3.4 and Chapter 6 of this primer.

The need for schools to consider sheltering in place is demonstrated in Figure 5-1, which depicts the results of modeling a chemical dispersion from a rail line assuming local prevailing winds. Note that the chemical plume travels directly over a nominal elementary school.

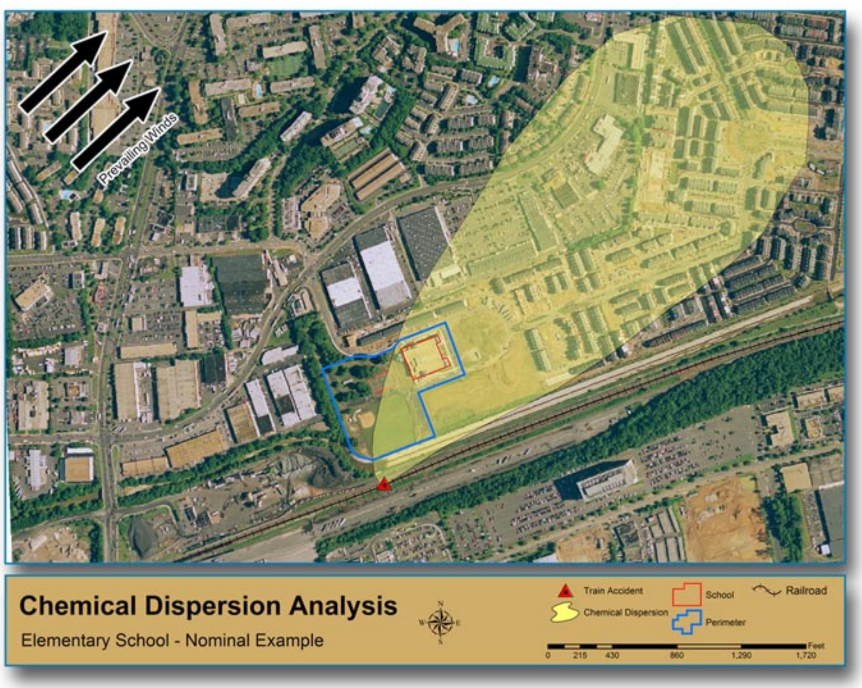

Figure 5-1 Example of chemical dispersion

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 school 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 school 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 students, faculty, and staff remain in the building after the hazardous plume has passed also affects the level of protection. Because the school 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 into clean air.

- **Natural filtering.** Some filtering occurs when the agent is deposited in the school shell or upon interior surfaces as air passes into and out of the building. The tighter the school 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 school 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 shell 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 school safe rooms (i.e., interior rooms having a lower air exchange rate – see Chapter 6) 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

Although sheltering is for protection against an external release, it is possible, but more complex, to shelter in place on one or more floors of a multi-story school building after an internal release has occurred on a single floor. 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 students, faculty, and staff cannot be forced to participate. During an event, some building emergency 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. 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. Training programs and information announcements during an event should be tailored to help students, faculty, and staff 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, and decontamination equipment.

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 bite on and breathe through a mouth bit or use straps to tighten a nose cup around the nose and mouth (see Figure 5-2). Escape hoods should be considered, but may not be an effective or efficient proposed solution for use in schools, under current threats.

SOURCE: MSA INTERNATIONAL

Figure 5-2 Universal-fit escape hood

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 about when to put on the hoods. Wearing a hood 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 school 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. Chapter 6 and FEMA 426 *Reference Manual to Mitigate Potential Terrorist Attacks Against Buildings* discuss air filtration in detail.

Two basic methods of applying air filtration to buildings 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 a 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 Section 5.2, the efficiency of the filter, flow rate of the filter unit, and size of the room or building in which the filter unit operates.

5.5 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 the hazard to which school occupants are exposed, 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 school 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 school 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 school building.

5.6 CBR DETECTION

Most strategies for protecting students, faculty, staff, and visitors from airborne hazards will 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; furthermore, wide varieties of efficient radiological detectors have been developed for the nuclear industry and are commercially available.

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).

Figure 5-3
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 5-3). They are suitable for integration into a building ventilation 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.

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. Because it is odorless and colorless, it causes many deaths in buildings each year (see Section 6.2.1).

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 emergency plans, 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 of warning properties, signs, and symptoms in other people is the basis of an emergency plan (see Sections 3.11 and 3.12). Such a plan should apply four possible protective actions: evacuating, sheltering in place, using protective masks, and exhausting 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.

CBR 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. **Most chemical warfare agents are gaseous, and biological and radiological agents are largely aerosols.**

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 5-1 and Figure 5-4).

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 5-2 and Figure 5-5). 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 5-3 and Figure 5-6). 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 5-1: 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.

Table 5-1: Indicators of a Possible Chemical Incident (continued)

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.)

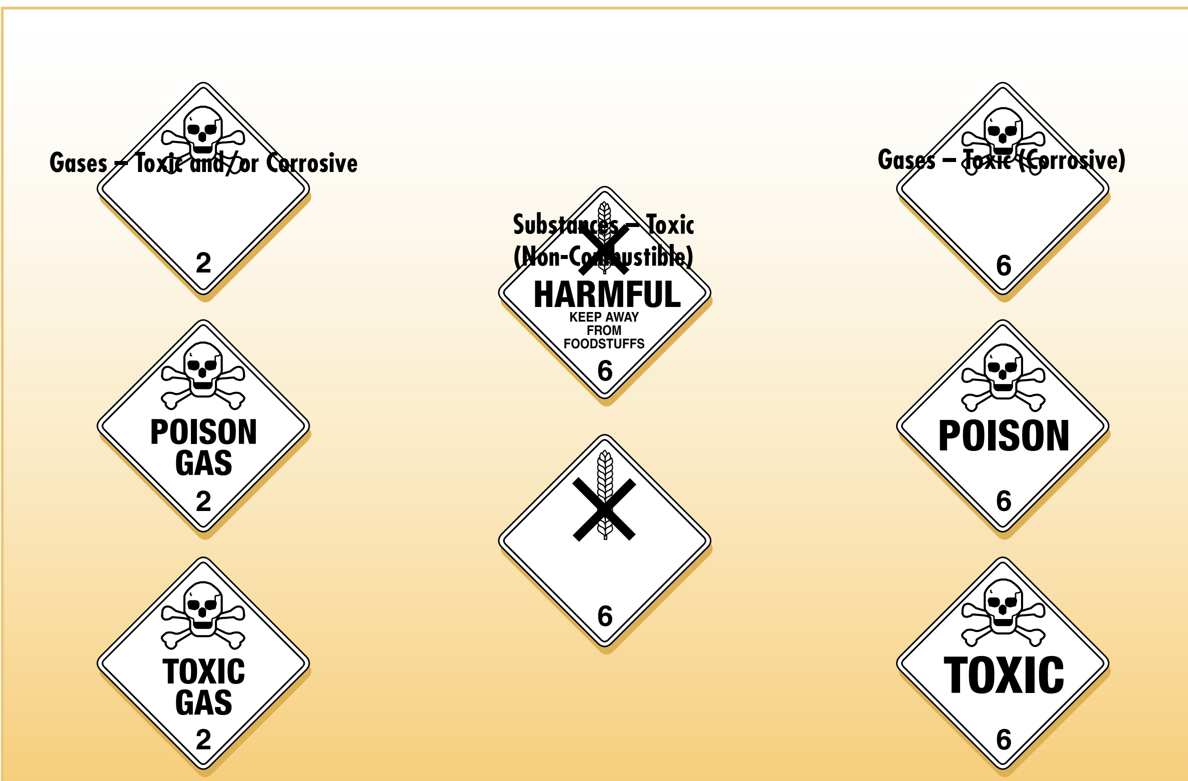

Figure 5-4 Placards associated with chemical incidents

Table 5-2: 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 causalities 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 5-5 Placards associated with biological incidents

Table 5-3 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.

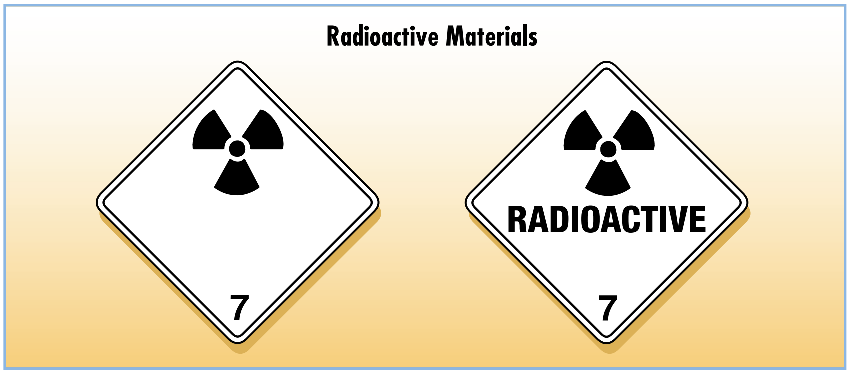

Figure 5-6 Placards associated with radiological incidents