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TI 853-01
October 2001

U.S. Army Corps
of Engineers ®

PROTECTING BUILDINGS AND THEIR OCCUPANTS FROM AIRBORNE HAZARDS

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PROTECTING BUILDINGS AND THEIR OCCUPANTS

FROM AIRBORNE HAZARDS

FOREWORD

This document presents a variety of ways to protect building occupants from airborne hazards -- to prevent, protect against, and reduce the effects of outdoor and indoor releases of hazardous materials. It contains guidance for building managers, designers, and security planners on how to minimize the potential effects of hazardous materials released in accidents, malicious acts, or natural phenomena.

These protective measures can be as simple as defining and implementing a protective-action plan. Some are design measures for new construction or retrofit that can reduce the likelihood that releases will affect building occupants. Others are security measures intended to prevent an internal release or an external release close to the building.

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PROTECTING BUILDINGS AND THEIR OCCUPANTS FROM AIRBORNE HAZARDS

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CHAPTER 1
INTRODUCTION

Each year there are hundreds of incidents in the United States in which airborne hazards – commonly referred to as hazardous fumes, noxious chemicals, or mysterious odors -- permeate buildings and cause illness, injuries, or disruption of activities. In most cases, these incidents result in evacuation -- the natural response in such emergencies and usually the only practical course of action by which occupants can reach clean air and safety.

Most of these involve accidental releases of chemicals, either inside or outside the building. Some may be the result of malicious acts -- vandalism, pranks, or in the extreme, terrorism. The deliberate release of toxic chemicals or biological aerosols (fine particles) into a building can be life-threatening and can have substantial economic impact.

Accounts of these incidents appear in newspapers regularly. The following are several examples from news articles that illustrate the effects of such incidents – involving both internal and external releases -- and the variety of ways they can occur.

- In Phoenix, Arizona, an unknown gas permeated a large office building, causing 2,500 employees to be evacuated and 80 to be taken to a hospital. The source of the gas was never determined, although it was suspected to have been released accidentally from a passing truck on a nearby freeway and to have entered through the building's fresh-air intakes.

- In North Arlington, Texas, 600 people were evacuated from an office building after fumes from an unknown source nauseated dozens of workers. Ten people in the building were treated at hospitals. Fire officials twice searched the building and performed numerous tests, but could not detect a problem.

- In Fort Worth, Texas, mysterious fumes sickened about 200 people in an office building, sending 72 to hospitals and creating hysteria as dizzy, teary-eyed victims stumbled from the building gasping for air, vomiting and, in some instances fainting. One victim said he didn't smell anything but saw people all around getting sick.

- In Eggertsville, NY, 100 nursing home residents and employees were evacuated after becoming ill from unidentified fumes inside the building. The fire department was called in response to complaints about odorless fumes that caused coughing, sneezing and tightness in the chest. Eleven people were treated at hospitals.

- At Fort Carson, Colo., a family counseling and communications center was evacuated after fumes caused headaches, nausea, and vomiting. Workers and clients in the center noticed a smell similar to jet or diesel fuel. Twenty-seven people were taken to a hospital.

- In Birmingham, Ala., herbicide vapors were drawn into the radar room in the airport's air traffic control tower after weeds were sprayed near the tower base. Symptoms of radar-room employees ranged from bloody noses to dizziness to euphoria, and seven were treated at a hospital. The vapors entered through the air-conditioning system and caused radar-room operations to be moved to another location.

- In Hackensack, N.J., police, firefighters, and utility crews searched for more than two hours for the source of fumes that forced hundreds of people out of the county courthouse. Later, officials said a few gallons of hydraulic fluid spilled from a piece of construction equipment was to blame for disrupting the courthouse schedule.

- In East Boston, Mass. mysterious fumes forced 1,400 students and teachers to evacuate a high school. Two teachers and two students were treated at a hospital, while 13 others were given water and oxygen on-site by emergency responders.

- In San Jose, Calif., three young men unleashed pepper spray inside four stores, exposing 128 people to eye-burning fumes, forcing evacuations and prompting one-fifth of the city's firefighters to be called out to treat them.

- In San Antonio, Tex., a truck overturned during morning rush hour on a ramp at the northwest corner of downtown, spilling 4,500 gallons of hydrochloric acid. About 5,000 people were evacuated from a three-square-mile area, including 2,600 students from several schools.

Even without special protective systems, buildings can provide protection in varying degrees against airborne hazards that originate outdoors. Such protection is limited and effective only under certain conditions, however. 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 or directly into a building, but hazards persist longer indoors.

This document presents a variety of ways to protect building occupants from airborne hazards -- to prevent, protect against, and reduce the effects of outdoor and indoor releases of hazardous materials. These protective measures can be as simple as defining a protective-action plan. Some are design measures for new construction or retrofit that can reduce the likelihood that releases will affect building occupants. Others are security measures intended to prevent an internal release or an external release close to the building.

Some of these protective measures are practical only for new construction, while others are suitable for retrofit of existing buildings. Also presented are low-cost, expedient measures-- operational procedures for reducing vulnerability or for mitigating the hazard once a release has occurred. The following protective measures are presented:

- High-efficiency filters for removing gases and aerosols from makeup air
- Recirculating filter units (indoor air purifiers) available commercially
- Physical security and entry screening measures
- Architectural and mechanical design measures
- Protective-action plans covering sheltering, evacuation, purging, and protective masks

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CHAPTER 2
PERTINENT FACTS ABOUT AIRBORNE HAZARDS

Most strategies for protecting people from airborne hazards require a means of detection -- 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.

Most hazardous chemicals, however, have warning properties, which provide a practical means for detecting a hazard and initiating protective actions. Such warning properties make chemicals *perceptible*; that is, the vapors or gases can be perceived by the human senses -- 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 War I and World War 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 the gas mask. An exception is the chemical-warfare agent sarin, which is odorless and colorless in its pure form, 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.

Biological agents are also imperceptible, and there are no detection devices that can determine their presence in the air in real time. It is therefore not currently possible to base protective responses to biological agents upon detection.

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 as described in Chapter 7. Such a plan applies four possible protective actions: sheltering in place, using protective masks, evacuating, and purging.

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.

For the purpose of defining protective measures for buildings, releases are divided into two general types -- external and internal releases.

External releases may result from accidents involving industrial storage or transport, fires, or malicious acts. An important consideration is that in outdoor releases, the source of the hazard is most likely to be at or near ground level. When gases or aerosols are released at ground level, they tend to remain at ground level under stable conditions, which normally occur at night, dusk, and dawn and on overcast days. On sunny days, when the ground is hotter than the air above it, plumes tend to spread upward and be diluted as they rise.

Plumes originating at ground level will, however, be diverted upward as they travel over buildings. In general, a plume will take the shortest path past a building. If the width of a building is more than twice its height, the shortest path will be *over* the building and the plume will travel upward to openings on upper floors.

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CHAPTER 3
DETERMINING A BUILDING'S PROTECTIVE CAPABILITY

A building is a system of barriers that protects the occupants from the environment. The barrier system is incomplete, however, in that it contains openings upon which winds, fans, and natural convection act to exchange indoor air with outdoor air. These openings are both intentional ones -- such as windows, doors, vents, and outside air intakes -- and unintentional ones such as cracks, joints, seams, and pores.

In general the protection a building provides against an external release is determined by these openings -- their locations, the forces that drive the exchange of air through them, and the presence of any air filters.

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

To a very limited degree, a building acts as a natural filter. Natural filtration occurs as a small portion of vapors, gases, and aerosols that enter a building become deposited in the building shell or upon interior surfaces as outdoor air flows into and through a building. To filter air at a high efficiency requires the use of special filters in a mechanical ventilation system.

Buildings with mechanical ventilation are designed to introduce outdoor air at a rate of about 15 to 20 cubic feet per minute (cfm) per person, so in normal operations, there is a constant potential for contaminants released outdoors to be transported indoors. In buildings with mechanical ventilation, the outside air enters predominantly through the fresh air intakes. A smaller portion enters by infiltration through cracks, seams, joints, and pores in the building shell.

Once contaminated air enters a building, the ventilation system can transport it rapidly to various parts of the building. Within each ventilation zone, it can be drawn through return ducts and distributed through supply ducts at high rates of flow. It can also be driven by chimney effect via stairwells or elevator shafts, particularly in winter when temperature differences between inside and outside are large. At ground level, the flow due to chimney effect is inward in winter and outward in summer; therefore, a ground-level release is more likely to be drawn into a building during the winter.

In fall and spring, buildings that use economizer systems typically introduce much greater volumes of outside air to reduce the operating costs related to air-conditioning. Contaminated air can also be transported between ventilation zones of a building by flow through hallways and occupied spaces of a building.

Buildings that do not have mechanical ventilation meet fresh air requirements by infiltration and natural ventilation. Though less tightly constructed, such buildings can be less vulnerable to external releases when windows are closed. With windows and doors closed, the paths of entry for outside air are smaller and more scattered than in buildings with mechanical ventilation systems.

The potential for an internal release of hazardous materials is determined by: 1) the presence of hazardous materials stored in the building, 2) security measures to prevent hazardous materials from being brought into the building, and 3) architectural and mechanical features to isolate or limit the spread of hazardous material if an internal release occurs. Hazardous materials can be carried into a building by people or in the delivery of mail, supplies, and equipment; therefore, the likelihood of an internal release is also determined by the accessibility of the building to the public and the presence of entry screening measures for people, mail, and supplies.

CHAPTER 4
ARCHITECTURAL AND MECHANICAL DESIGN FEATURES FOR PROTECTION

Several design measures can be applied to reduce the potential for hazardous materials entering a building from a ground-level, outdoor release.

Elevating Fresh-Air Intakes

Elevating the fresh-air intakes is most easily applied in new construction. This has two main benefits.

- It provides passive security against malicious acts, making it more difficult for a container of hazardous material to be inserted directly into the building's HVAC system and to be conveyed to various parts of the building.

- It makes it less likely that high concentrations of hazardous material will occur at the intakes if there is a ground-level release *near* the building. A common problem with ground-level intakes near streets or parking areas is that exhaust fumes can be drawn indoors under certain conditions of wind and stability. In elevating the intakes, the dilution increases with the distance from the source. In stable conditions, contaminants released near the ground will likely remain close to the ground unless the airflow over the building lifts it upward. Contaminants that are heavier than air will also tend to remain close to the ground under calm conditions.

The effectiveness of elevating intakes has practical limits. A plume or cloud of hazardous materials can reach the intakes, particularly if the source is large and distant. For low-rise buildings, those having a width more than twice the height, a plume originating at ground level near the building will travel over the building rather than around it; thus, the wind will convey contaminants to the top of the building, with some dilution occurring.

Intakes should be placed at the highest practical level on the building. For protection against malicious acts, the intakes should also be covered by screens so that objects cannot be tossed into the intakes or into air wells from the ground. Such screens should be sloped to allow thrown objects to roll or slide off the screen, away from the intake.

Many existing buildings have air intakes that are located at or below ground level. For those that have wall-mounted or below-grade intakes close to the building, the intakes can be elevated by constructing a plenum or external shaft over the intake.

Providing Security for Existing Fresh Air Intakes

For existing buildings with air intakes below grade, at ground level, or wall-mounted outside secure areas, some protection can be gained with physical security measures -- placing fencing around the intake and surveillance cameras and motion detectors on it to be monitored by security personnel. These measures can help prevent malicious acts but are less effective than elevating the intakes, as ground level releases under certain conditions can enter the intakes from points outside the area fenced or under surveillance.

Securing Mechanical Rooms

Maintaining physical security on mechanical rooms is a simple measure to prevent the direct introduction of hazardous materials into the system of ducts that distributes air to the building. It requires locking and controlling the access to all mechanical rooms containing HVAC equipment, both with interior doors and exterior doors.

Isolating Entry and Storage Zones

For buildings having access control, there are three entry zones of concern regarding deliberate internal releases of hazardous materials. These entry zones are 1) the lobby, in which people await entry into the secure area of the building; 2) the mailroom in which mail is received for distribution; and 3) the area in which supplies or equipment are received and held temporarily awaiting distribution.

If people, mail, or supplies/equipment enter the building before being screened, the ventilation system of the entry area or lobby area in which they await screening should be isolated from the rest of the building. This is to prevent the movement of airborne hazards to the protected areas of the building if a release occurs before security screening. This isolation is achieved by:

- A separate air handling unit for the entry area
- Exhaust fan(s) to create a slight negative pressure differential in the entry area
- Full-height walls surrounding the entry area
- An airlock or vestibule for exterior doors to maintain the pressure differential as people enter and exit. If entries are infrequent, an airlock is not essential, particularly for mailrooms or supplies receipt areas.

Isolated entry zones can be incorporated in both new designs and retrofit. These measures can also reduce the potential disruptive effects of hoax letters purported to contain hazardous materials.

Isolating storage areas where hazardous materials are kept or processed within a building, is also addressed by building fire codes. The approach for isolation of storage areas is similar to that applied for entry areas.

Separation of Zones

Large buildings usually have multiple HVAC zones, with each zone served by its own air handling unit and duct system. In practice, these zones are not completely separated if they are on the same floor. Air flows between zones through hallways, atria, and doorways that are normally left open.

Isolating the separate HVAC zones minimizes the potential spread of an airborne hazard within a building, reducing the number of people potentially exposed if there is an internal release. Zone separation also provides limited benefit against an external release, as it increases internal resistance to air movement produced by wind forces and chimney effect, thus reducing the rate of infiltration. In essence, isolating zones divides the building into separate environments, limiting the effects of single release to an isolated portion of the building. Isolation of zones requires full-height walls between each zone and its adjacent zone and hallway doors.

Securing Exterior Windows

Having secure windows can prevent certain types of intentional or malicious acts involving grenades or thrown dissemination devices. Securing windows includes locking against forced opening and specifying windows resistant to being broken by thrown objects.

Single-Switch Controls for Sheltering in Place and Purging

Sheltering in place (discussed in Chapter 6) is a protective action for use against an external release for which there is forewarning. This protective action requires that all fans that produce air exchange -- fresh-air fans, exhaust fans, and air handling units -- be turned off before the cloud of hazardous material envelopes the building.

In large buildings, controls or switches for deactivating these fans are often in diverse locations that may not be easily accessible in the short period available after a warning is received. To be effective, sheltering must be implemented rapidly; therefore, it is important to have the ability to turn off these fans quickly. This can be achieved by adding a single-switch control, installing relays for turning off all fans affecting outside air exchange or if the building is so equipped, modifying the fire alarm control panel to de-energize the ventilation system and close the outside air dampers. The switch should be located where it is readily accessible to the facility manager or building security personnel.

This protection can be enhanced by installing automatic dampers on outside air intakes and on exhaust fans not already equipped with back-draft dampers.

A third measure for enhanced passive protection is to provide controls for smoke purge fans that will allow the building, or selected floors, to be purged rapidly by the introduction of outside air at high rates of flow. This capability has two applications: 1) after an internal release, and 2) once the hazardous plume has passed when sheltering in place.

Vestibules

Vestibules, airlocks, and revolving doors provide a means of controlling infiltration at main entrances as people enter and exit. These are most beneficial in multistory buildings when there are large indoor-outdoor temperature differences, i.e. in winter and summer. At the entrance, the flow is inward in winter and outward in summer; therefore, contaminants released at ground level near the building are most likely to be drawn in by chimney effect during winter.

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CHAPTER 5
SECURITY MEASURES TO PREVENT AN INTERNAL RELEASE

Generally, there are two ways to protect against an internal release of hazardous materials. The first is to prevent containers of hazardous materials from being brought into a building in the routine flow of people, mail, and supplies. The second is to employ zone isolation, purging, or internal filtration to minimize the effects if an internal release occurs.

Prevention involves physical security measures to exclude containers that may hold hazardous materials. This requires integrating procedures for detecting and examining such containers into the access control and entry screening procedures of the building. These procedures, for preventing the intentional, malicious release of hazardous materials in a building, must be rapid and simple enough for application with the routine security measures.

Entry screening is a two-step process -- first, detecting a closed container and second, determining whether the contents of the container are likely to be hazardous. Step one involves the use of the existing x-ray system, metal detector, or a manual search of briefcases, handbags, packages, letters, or boxes of supplies. Items to be excluded or further examined are:

- Aerosol cans or other pressurized containers
- Manual or electric spray devices
- Containers of liquids or powders
- Bottled gases typically used for repair or maintenance within the building
- Pressurized dispensers containing irritating agents such as pepper spray, mace, or tear-producing agents

Step two involves examining the container, its contents, and labels and determining whether the contents agree with the label. Liquid or powder in containers having no label is reason for exclusion. This step involves examination for alterations and obvious indications that the contents do not agree with the label. For liquids, it can also involve the use of ultrasonic detection devices to determine if the contents agree with a known standard of similar material.

Zone isolation, purging, and internal filtration to minimize the effects of an internal release are discussed in other sections of this document.

CHAPTER 6
PROTECTIVE ACTIONS FOR PERCEPTIBLE HAZARDS

Once the presence of an airborne hazard is detected, there are four possible protective actions: evacuating, sheltering in place, using protective masks, and purging.

These actions, of course, do not provide protection on a continuous basis but are implemented – singly or in combination -- for relatively short periods when a hazard is present or known to be imminent. These measures apply only to perceptible chemicals, agents detectable by automatic detectors, or in response to events, such as an explosion or a highway or rail accident involving toxic industrial chemicals.

To ensure that these actions will be effective requires a protective-action plan specific to each building, as well as training and familiarization for building occupants. Protective action plans are discussed in Chapter 7.

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, but in all situations it may not be the best action for an external release, particularly one that is widespread. If the area covered by the hazardous plume is too large to exit from rapidly, the use of sheltering in place should be considered.

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.

If the source is external, and agent has infiltrated the building, evacuation is not the safest option, and the use of protective masks is appropriate. Sheltering in place may also be employed, but generally should not be employed once the hazardous material has begun to enter a building.

Evacuation may lead to other risks, taking the occupants from the physically secure environment of the building into the streets. Evacuation routes may also be hazardous in that they may take people through contaminated areas as they leave the building.

Sheltering in Place

Sheltering in place and evacuation are two protective actions planned for and employed by many U.S. communities in the event of an accidental release of toxic chemicals. The advantage of sheltering in place is that it can be implemented rapidly. The disadvantage is that the protection it provides is variable and diminishes with the duration of the hazard.

Sheltering in place requires two distinct actions to be taken without delay to maximize the passive protection a building can provide.

- First, reducing 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, increasing 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.

Though tightly sealed, a building does not prevent contaminated air from entering; it minimizes the rate of infiltration. Outside air enters more slowly, and once the external hazard has passed, the building releases the contaminated air slowly as long as it remains closed.

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

- The building's air exchange rate. The tighter the building -- the lower the air exchange rate -- the greater is 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 two hours or less, depending upon conditions.

- Purging or period of occupancy. How long occupants remain in the building after the hazardous cloud has passed also affects the level of protection. Because the building slowly releases contaminants that have entered, at some point during cloud passage the concentration inside exceeds the concentration outside. Maximum protection is attained by increasing the air exchange rate after cloud 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 is the effect of this natural filtering.

In a home, taking the actions required for sheltering -- closing windows and doors and turning off all air conditioners, fans, and combustion heaters -- is relatively simple. Doing so in an office 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 the procedures for purging the building after an internal release – opening operable windows and doors, turning on smoke fans, and turning on the air handlers and fans that were turned off to shelter.

- Identifying safe rooms, interior rooms having a lower air exchange rate that may provide a higher level of passive protection.

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 building after an internal release has occurred on one floor. Important considerations for use of sheltering in place under such conditions are that stairwells must be isolated by closed fire doors, that elevators must not be used, and that clear evacuation routes must remain open if evacuation is required. Escape masks may be needed if the only evacuation routes are through contaminated areas.

Use of Ventilation System and Smoke Purge Fans

Turning on a building's ventilation fans and smoke-purge fans is a protective action for purging the hazardous material from the building and reducing the hazard to which building 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 building, and if not, purging must not be attempted. If the hazardous material has been identified before release or immediately upon release, purging should not be employed, as it may spread the hazardous material throughout the building or zone. In this case, all air-handling units should be turned off to isolate the hazard while evacuating or temporarily sheltering in place.

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

Use of Protective Masks

New models of universal-fit escape masks have been developed for short duration "escape-only" protection against chemical and biological agents and some toxic industrial chemicals. These masks are compact enough to be stored at desks or to be carried on the belt. They must be stored in their sealed pouches and opened only when needed. These masks do not require special fitting techniques or multiple sizes to fit most of the population. Training is required to use the masks properly. Depending on mask design, the wearer must bite down and breathe through a mouth bit or use straps to tighten a nose cup against the nose and mouth. The neck seal alone provides only limited protection.

The protective capability and shelf life of the masks varies depending on the design. The filters of these masks contain both high-efficiency particulate air (HEPA) filtering media 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 masks is that their filters are not effective against certain chemicals of high vapor pressure. Chemical masks provide no protection against carbon monoxide from a fire. Check the manufacturer data closely when ordering. Other escape hoods are available that employ compressed oxygen cylinders, rather than air filters, to provide eye-respiratory protection for very short periods.

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CHAPTER 7
DEVELOPING A PROTECTIVE-ACTION PLAN

Whether it is practical to employ one or all of the four protective actions described in Chapter 6, a protective-action plan is important in an emergency involving airborne hazards. A protective-action plan provides the ability to respond rapidly to perceptible hazards of all types and to select the best course of action. There are four steps in preparing and implementing a protective action plan:

- Conduct a building survey to determine what protective actions are practical for the building and what hazardous chemicals are stored, used, or transported in or near the building.

- Write specific procedures for:
  Determining if/when a hazard exists
  Deciding upon the best action to take, based on conditions and events
  Communicating emergency instructions to all in the building
  Evacuating, sheltering, purging, and/or using masks

- Designate and train protective action coordinators

- Train and familiarize those who work or reside in the building on awareness and the procedures to be taken in a hazardous-materials emergency.

Conducting a Building Survey

The purpose of the building survey is to gather information about the ventilation system and the characteristics that determine the building's protective capability.

Identify features pertinent to protective actions:
- Determine the building's type of ventilation system -- natural ventilation, unit ventilators (through-the-wall units in each room) or a duct system with air handling units.
- If the building has a duct system, record the number of different zones and air handling units, and the locations of switches for each.
- Determine if the building has smoke purge fans and whether the intakes of the smoke purge fans are at ground level or elevated.
- Record the locations and identification of switches for the smoke purge fans.
- Determine if the building has automatic dampers in working condition on outside-air fans and air handlers.
- List all exhaust fans and the location and identification of the control for each.
- Determine if stairwells are protected from smoke (external and isolated).
- Determine whether the building has a public address system. If so, record the locations of the broadcast microphone and controls.
- Record the information on communicating with building security personnel.
- Obtain a copy of the evacuation routes posted for a fire emergency.
- Determine if there are interior rooms suitable for sheltering "safe rooms".

Gather information on hazardous chemicals stored or used in proximity:
- Determine what hazardous chemicals, if any, are stored in the building and their storage locations.

age locations.
- Determine what hazardous chemicals are used in the building on a regular basis.
- Obtain the material safety data sheets (MSDS) for these chemicals and record the warning properties listed.
- Determine what ventilation systems (such as hoods or glove boxes) are in place to contain or isolate a release of these chemicals at the source.
- Query the Local Emergency Planning Commission about hazardous chemicals that are stored, processed, or frequently transported near the building. Compile a list of these, their approximate distance and direction from the building, and their warning properties.

Identify features that make the building vulnerable to accidental releases or malicious acts:
- If the building has mechanical ventilation with a duct system, record the location of all fresh air intakes that are at ground level and accessible to the public.
- List the locations of mechanical rooms having air handlers, whether each mechanical room is kept locked, and which have outside entrances.
- Determine whether the lobby and any public access areas of the building share an air-handling unit with office areas.
- Determine if security screening procedures are in place to prevent hazardous materials from being brought into the building.

Selecting a Warning System

A public address system to all parts of the building is the most efficient means of communicating emergency instructions. The telephone can also be used but is less efficient. A tone-alert or audible alarm system can also be used as long as the alarm sounds are easily distinguished from a fire alarm. Non-verbal warning systems, however, are more dependent upon training and familiarization of all building occupants and are generally less effective than oral instructions.

Designating the Protective-Action Coordinators

The job of protective action coordinator (PAC) is similar to that of the building fire marshal. The PAC is given the decision-making responsibility to evacuate, shelter in place, use protective masks, or turn off/on the fans in the building. The PAC also contacts emergency response personnel when a hazard occurs. There should be a PAC designated for each duty cycle or shift, and each PAC should have a thorough understanding of the protective action plan. The PAC must be accessible by pager, radio, phone, or direct communication at all times.

Conducting Training

Training the people who work or reside in the building on procedures for airborne hazards has three objectives:

- To develop an employee awareness of potential airborne hazards. When trained, the building occupants can serve to detect hazards and to reduce the time to respond by being aware of odors, symptoms, or suspicious activities. The training should include familiarization with the warning properties of hazardous chemicals stored or used in or near the building, information on what actions are to be taken, and awareness of suspicious activities relating to fresh air intakes, mechanical rooms, and abandoned parcels within the building.

- To develop an understanding of the responses and protective actions, what to do for each of the possible protective actions.

- To inform building occupants about the PACs, their job, and how they can be contacted.

Developing the Protective Action Plan

Based upon information gathered in the building survey, determine whether it is possible to employ sheltering in place, purging, protective masks and evacuation in an emergency. Evacuation is practical for virtually all buildings. Sheltering in place is practical in most buildings. Purging is most effective if the building has smoke purge fans. To use masks requires that protective masks, referred to as escape masks, have been or will be issued to the people who work or reside in the building.

Defining criteria for initiating protective action

The plan should list criteria for the PAC to apply in initiating protective actions, that is, for determining whether a hazard exists that requires emergency action. The following are indications of an airborne hazard.

Sensory indications
- Strange or pungent odor in the building
- Irritation of the eyes or throat experienced by people in the building
- Smoke or a fog in the building
- Unusual noises, such as the release of gas under pressure in or near the building

Symptoms
- People reporting nausea, collapse, choking, or irritation of the eyes or throat
- Observing these symptoms in other people in the building

Evidence indicating malicious acts
- Finding a spray device in or near the building (pressurized cylinder, batteries with pump and nozzle, container of liquid, gas, or powder)
- Finding a suspicious parcel left unattended in the building
- Receiving a letter or parcel with markings indicating hazardous materials
- Receiving a threat

Information reported on a hazardous release
- Notification from authorities that there is an outdoor hazard, such as an accident involving a storage site, tanker truck, or rail car
- Notification that there is an internal spill of cleaning material, or a release of hazardous material stored indoors.

Defining the decision-making process

Once it is apparent that an airborne hazard exists in the building, the most important step in deciding on the best protective action is to quickly determine whether the source of the hazard is *inside or outside* the building. Recognizing that it may not always be possible to quickly do so, the best approach is to take action based on the *most likely* location while continuing to investigate.

If the source is clearly inside, such as a spill of cleaning solution or an accident causing the release of hazardous chemical stored in the building:

- Shut down all air-handling units until the type of hazard and extent of its spread can be determined.
- Evacuate the affected floor(s).
- If people may be exposed to the hazard along evacuation routes, consider the use of protective masks based upon indications of the type of hazardous material (masks may not provide protection for certain types of chemicals).
- If the hazard it is a perceptible agent, initiate purging with smoke fans, if available.

If the source is inside and contained or localized, such as a package containing a toxic material:

- Shut down all air-handling units that serve the affected floor.
- Isolate the affected area by closing doors and fire doors.
- Communicate with the fire department for assistance.
- Evacuate the affected floor(s) via routes away from the affected area.
- If people may be exposed to the hazard along evacuation routes, consider the use of protective masks, if available.

If the source is clearly outside:

- Initiate sheltering procedures and communicate with the fire department about the likely duration of the event (how long until the release will be contained). Sheltering is appropriate if the hazard is known to originate outside the building and if there is no indication that the hazardous material has begun to enter the building.
- If the hazardous material has begun to enter the building, use protective masks if available.

If the source location cannot be quickly determined:

- If there is an odor or other signs, use protective masks, then determine if the air is clean outside the building. If so, evacuate.
- If there are symptoms -- but no odor or other sensory indications -- evacuate
- Check for other possible indicators of source:
    - In a multistory building, if signs/symptoms are not apparent on adjacent floors, it is likely an internal release on one floor.
    - If there are visible signs outside the building, such as people fleeing or responding to an airborne hazard, it is likely an external release.

Defining Procedures for Protective Actions

The following are basic considerations and procedures for the four protective actions that should be addressed in the plan.

- **Sheltering in Place**. Prepare a list of all switches that control air-handling units, outside air fans, exhaust fans, and unit ventilators or room air conditioners. Describe the location of each switch in the plan and mark each switch with a label "for sheltering in place". The procedure for terminating sheltering in place is to turn on all fans as soon as authorities determine the hazard outdoors has passed. Smoke purge fans should also be used for this sheltering termination procedure, if available, and the switches controlling these fans should be marked and listed. If the building is equipped with a fire alarm control system, the fire alarm system can be modified with a shelter in place mode to de-energize the ventilation system and close outside air intakes. Additionally, if the building ventilation is so equipped, a purge mode can be used to turn on the ventilation and smoke purge system.

- **Evacuation**. Examine the fire evacuation routes available for the building. For those routes that pass through the main lobby, define alternate routes that do not, as it is preferable to have evacuation routes available that do not pass through the main lobby. For multistory buildings, the use of elevators should be avoided because elevator movement promotes the exchange of air between and among floors.

- **Purging**. Prepare a list of the switches that control the ventilation and smoke purge fans, their locations, and description. Describe the location of each switch in the plan and mark the switches as purge-fan controls. The use of ventilation and purge fans is primarily for an internal release. If the intakes for the purge fans are elevated on a high-rise building, the purge fans may be used even if the source is unknown (inside or outside the building). If purge fan intakes are at ground level, they must not be used if there is a possibility the source is outdoors.

- **Using Masks**. If masks have been issued, ensure that training is conducted on how to put on and wear the masks. A record of the manufacture date of each mask should also be maintained, so that the masks can be replaced when their shelf life has expired. The plan should list situations in which the mask would not provide protection, based on the types of chemicals stored or used regularly in the building or in proximity to it. Carbon monoxide and formaldehyde are examples of gases that may not be filtered by the canister of an escape mask. If there is uncertainty regarding a specific chemical, call the manufacturer of the mask. List in the plan the characteristic warning properties of chemicals used/stored in or near the building for which the mask is not effective. Material safety data sheets for hazardous materials stored in the building should be on file in the building.

Preparing Messages

A warning message should be prepared beforehand for each of the protective actions that are practical for the building. This will ensure that the actions can be taken as rapidly as possible and that the instructions will be clearly understood.

The messages should be worded to be effective without causing panic. An example of a warning over the intercom: “Attention, there is an unusual odor on parts of the second floor. If you are on this floor, proceed down the stairs and exit the building into the parking lot.”

Messages for evacuation may require instructing people to avoid certain areas that are known to present a hazard. Messages for sheltering in place may require instructions on turning off fans or closing windows. In buildings with unit ventilators, sheltering messages require instructions for turning off the ventilators. In buildings with natural ventilation, they require instructions for closing all windows and doors.

Defining Special Procedures

The plan should also include procedures for special situations as described below:

- **Capturing a Sample**. If an emergency involving an airborne hazard occurs in a building, it is beneficial to identify the chemical or aerosol producing the hazard. There are three purposes for this identification: 1) to know the proper medical treatment to be administered if people become ill, 2) to help determine the cause or source of the hazard, and 3) to obtain forensic evidence if the release is a result of a deliberate act. To identify the chemical or aerosol requires capturing an air sample or in some cases a liquid sample. Methods for such sampling are beyond the scope of this document; however, air-sampling equipment is available for capturing aerosols and chemicals. Chemicals of high vapor pressure tend to dissipate rapidly, so the samples should be taken as soon as possible without exposing people to the hazards. Air sampling may also be necessary for an all-clear determination, to ensure it is safe to return to the building and resume normal operations. Assistance in this sampling can be obtained from the fire department.

- **Dealing with Mail that May Contain Toxic Substances**. Mail may be received in the mailroom with notes or signs indicating a toxic substance is enclosed. Although these are likely to be hoaxes, they must be treated in a manner that prevents release and spread of the material if it is indeed hazardous. The simplest procedure is to place a container suitable for hazardous waste in the mailroom and designate it for letters that may contain toxic substances. If such a letter is received, it should be placed in the container, with care to handle letter carefully in a manner that will not aerosolize powder or cause release from the letter or package. Once contained, the item should be handled as hazardous material and be provided to authorities for testing and forensic analysis.

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CHAPTER 8
APPLYING AIR FILTRATION SYSTEMS TO BUILDINGS

Among the various protective measures for buildings, high-efficiency air filtration provides the highest level of protection against an outdoor release of hazardous materials. It can also provide continuous protection, unlike other approaches in 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 and discharging it 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 and discharging it inside.

The relative levels of protection of the two methods can be illustrated in terms of protection factor, the ratio of external dose (concentration integrated over time) and internal dose. 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 than 100 and they are highly variable. The protection of internal filtration varies with a number of factors, including those listed in Chapter 7 on 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.

HEPA filters are used for high-efficiency filtration of aerosols. Filter beds of activated, impregnated carbon or other sorbents are used for high-efficiency filtration of chemical vapors and gases. A carbon filter is always employed in series with a HEPA filter; however, a HEPA filter is often employed without a carbon filter if the requirement is only to remove aerosols from the air. HEPA filters, which are much less costly than carbon filters, are commonly used in hospitals, clean rooms, and even in some homes.

The efficiency of a HEPA filter is at least 99.97 percent; that is, only 0.03 percent of particles of a certain size range that enter the filter will exit the filter. Carbon filters can have a wide range of efficiencies, but those for protection against toxic chemicals are usually designed to maintain an efficiency of at least 99.999 percent throughout their intended service life.

A carbon filter removes molecules from an air stream by the process of adsorption, trapping molecules in the pores of the carbon granules. This process works best against large molecules, that is, chemicals of low vapor pressure. Activated carbon is an effective sorbent for removing a broad range of chemical vapors because of its extensive microporosity and wide range of pore sizes. Typically, the pores in highly activated carbon have a total surface area of over 1,000 square meters per gram.

Filtering chemicals of high vapor pressure requires a chemical reaction with impregnants added to the carbon. These impregnants react with the gas passing through the filter to form products that are innocuous or that can be retained by the filter.

Applying External Filtration to a Building

Applying external filtration to a building requires modifications to the building's HVAC system and electrical system, and it 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 pressure, 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 shell. 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 leakage rate of office buildings typically varies from roughly 0.1 cfm per sq ft to 2 cfm/ sq ft at a pressure of 50 Pascals, depending upon the type of construction. The cost of installing a high-efficiency filtration system varies directly with the leakage rate. An average building may cost $50 per square ft of protected floor space, but the cost varies with the leakage rate and the need for additional heating and cooling capacity for the filtered air.

Guidance on designing and installing positive-pressure collective protection systems is available in Corps of Engineers Engineering Technical Letter 1110-3-498, entitled, "Design of Collective Protection Shelters to Resist Chemical, Biological and Radiological (CBR) Agents".

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. Data on the leakage rates of various types of buildings are available in the ETL 1110-3-498 for estimating leakage rates of a building.

Various types of high-efficiency filter systems, both commercial and military systems, have been applied for building protection. The 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 -- areas having or requiring high rates of air exchange with the outdoors, such as mechanical rooms containing boilers or generators. 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, water gauge (iwg), 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 iwg. Maintenance costs involve periodic replacement of filters.

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 three years of continuous use with ASZM-TEDA carbon, depending upon the quality of air in the environment it operates.

Applying Internal Filtration (Recirculation Filter Units)

Internal filtration can be applied much more easily to a building -- in many cases without any modifications to the building or installation costs. Internal filtration, however, provides a much lower level of protection against an external release than does high-efficiency external filtration. One advantage of internal filtration, however, 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 is exchanged with outdoor air. The tighter the building, the higher is the level of protection achieved with internal filtration. Recirculation filter units can be employed to increase the 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. There are many of these on the market that 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 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 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 HEPA filters or low-efficiency carbon filters in place of standard dust filters in air handling units. Air handling units are not designed, however, to accommodate a large increase in airflow resistance a HEPA filter or thin carbon filter would add. The capability of the 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; this reduces the overall efficiency of the HEPA filters.