Unit VIII
Chemical, Biological, and Radiological (CBR) Measures

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Unit Objectives

Explain the five possible protective actions for a building and its occupants.

Compare filtration system efficacy relative to the particles present in CBR agents.

Explain the key issues with CBR detection.

Identify the indications of CBR contamination.

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Unit VIII: CBR Measures

Units I-VI covered the Risk Assessment Process

Units VII and VIII explain Explosive Blast, CBR Agents, and their effects

Units IX and X demonstrate techniques for site layout and building design to counter or mitigate manmade threats and similar technological hazards

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CBR Measures: An Overview

FEMA 426, Chapter 5 is based on best practices for safeguarding building occupants from CBR threats. This module is organized into four sections :

- Protective Actions for Buildings and Occupants
- Air Filtration and Cleaning Principles and Technology
- CBR Detection and Current Technology
- Non-Technology CBR Contamination Indications

SOURCE: SENSIR TECHNOLOGIES

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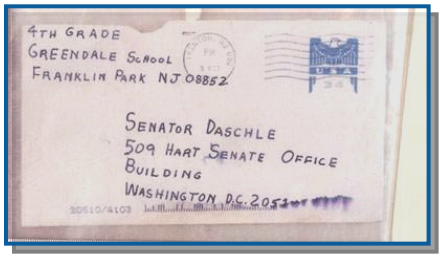
CBR Terrorist Incidents Since 1970



1972 Typhoid

1984 Salmonella
200 Injured

1984 Botulinum

1985 Cyanide

June 1994 Sarin
7 Dead, 200 Injured

1992 Cyanide

March 1995 Ricin

March 1995 Sarin

April 1995 Sarin

May 1995 Plague

April-June 1995 Cyanide, Phosgene, Pepper Spray

February 1997 Chlorine
14 Injured, 500 Evacuated

April 1997 U235

June 1996 Uranium

November 1995 Radioactive Cesium

December 1995 Ricin

March 1998 Cesium-137

2001 Anthrax

70 75 80 85 90 95 00

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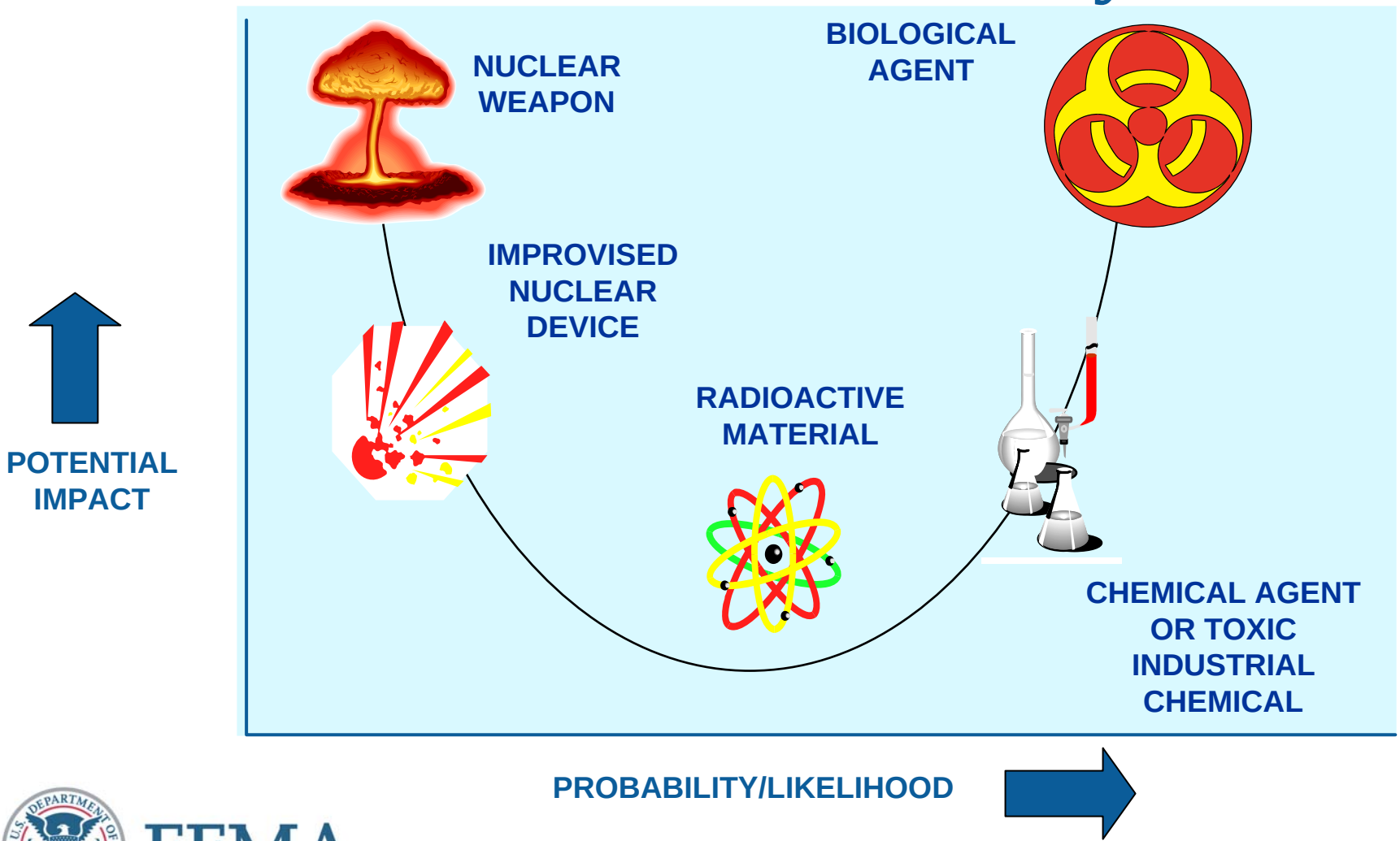
What is the CBR Threat Today?



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Why Would Terrorists Use CBR?

- Available and relatively easy to manufacture
- Large amounts not needed in an enclosed space
- Easily spread over large areas
- Potential for mass casualties
  - Strong psychological impact
  - Overwhelms resources
  - Difficult to recognize (contagious or spread by victims)

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CBR Sources

- Laboratory/commercial
- Industrial facilities
- Foreign military sources
  - At least 26 countries possess chemical agents or weapons
  - 10 countries are suspected to possess biological agents or weapons
- Medical/university research facilities
- Nuclear facilities
- Home production

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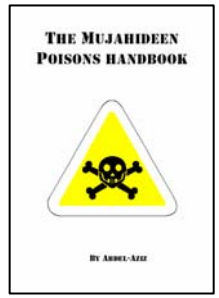
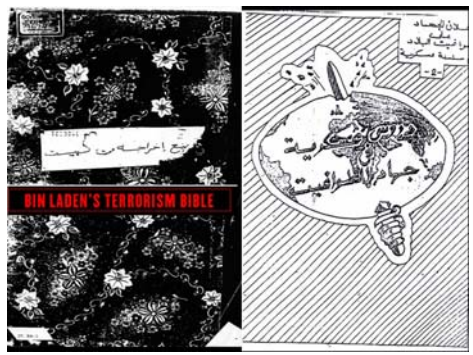
Limitations of CBR Materials

- Targeted dissemination is difficult
- Delayed effects can detract from impact
- Counterproductive to terrorists' support
- Potentially hazardous to the terrorist
- Development and use require time and expertise





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Chemical Agents: Characteristics and Behavior

- Generally liquid (when containerized)
- Normally disseminated as aerosol or gas
- Present both a respiratory and skin contact hazard
- May be detectable by the senses (especially smell)
- Influenced by weather conditions

Subway riders injured in Aum Shinrikyo sarin gas attack, Tokyo, March 20, 1995. (AP Photo/Chikumo Chiaki)

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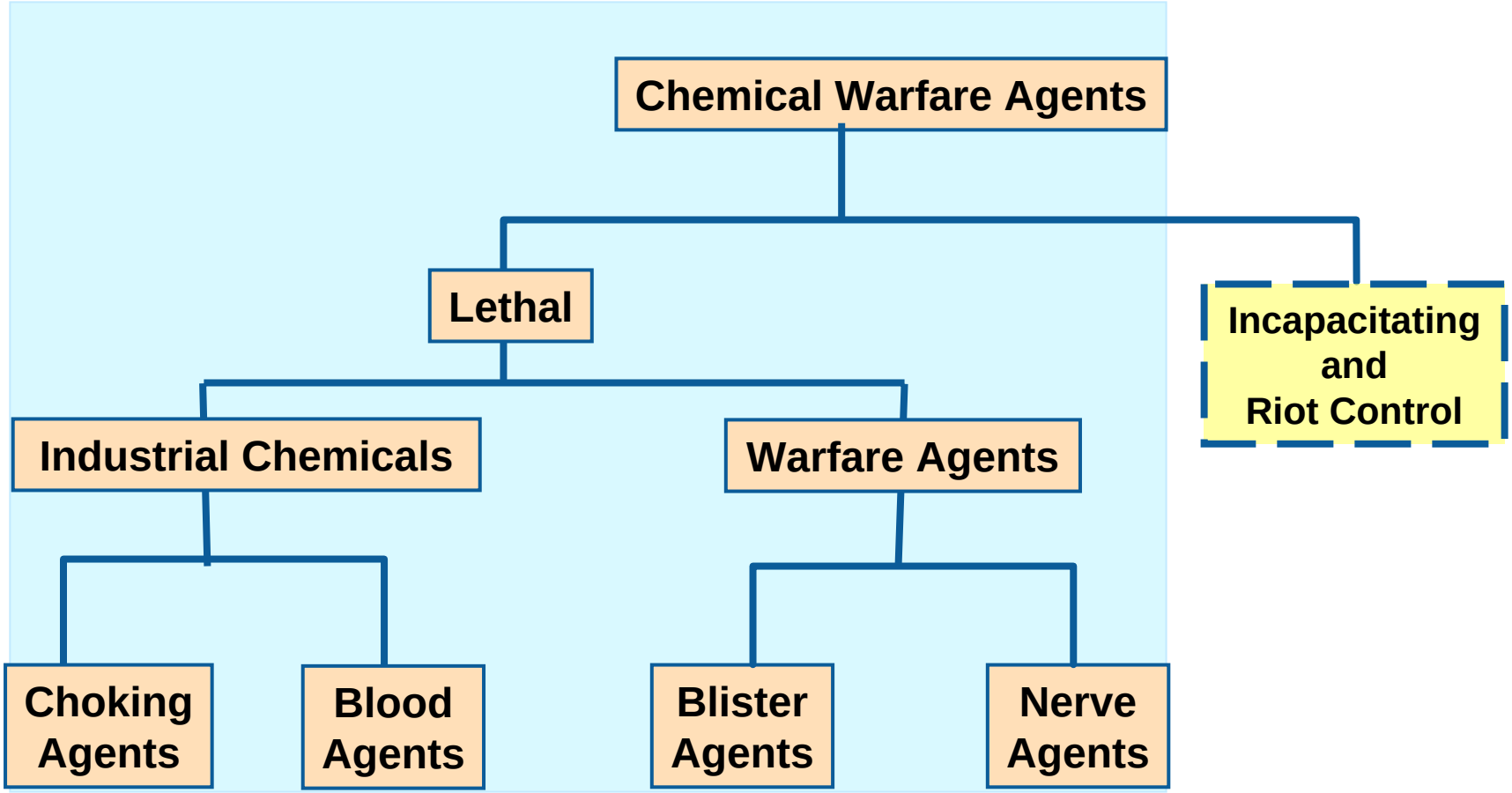
Classes of Chemical Agents



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Industrial Chemicals

Industrial chemicals previously used as chemical warfare agents	Choking Agents Chlorine/Phosgene	Blood Agents Hydrogen Cyanide/ Cyanogen Chloride
Physical Appearance	Greenish-yellow vapor/ colorless vapor	Colorless vapor
Odor	Bleach/mown hay	Bitter almonds
Signs and Symptoms	Coughing, choking, tightness in chest	Gasping for air Red eyes, lips, skin
Protection	Respiratory	Respiratory
Treatment	Aeration	Aeration, cyanide kit

Four industrial chemicals previously used as chemical warfare agents

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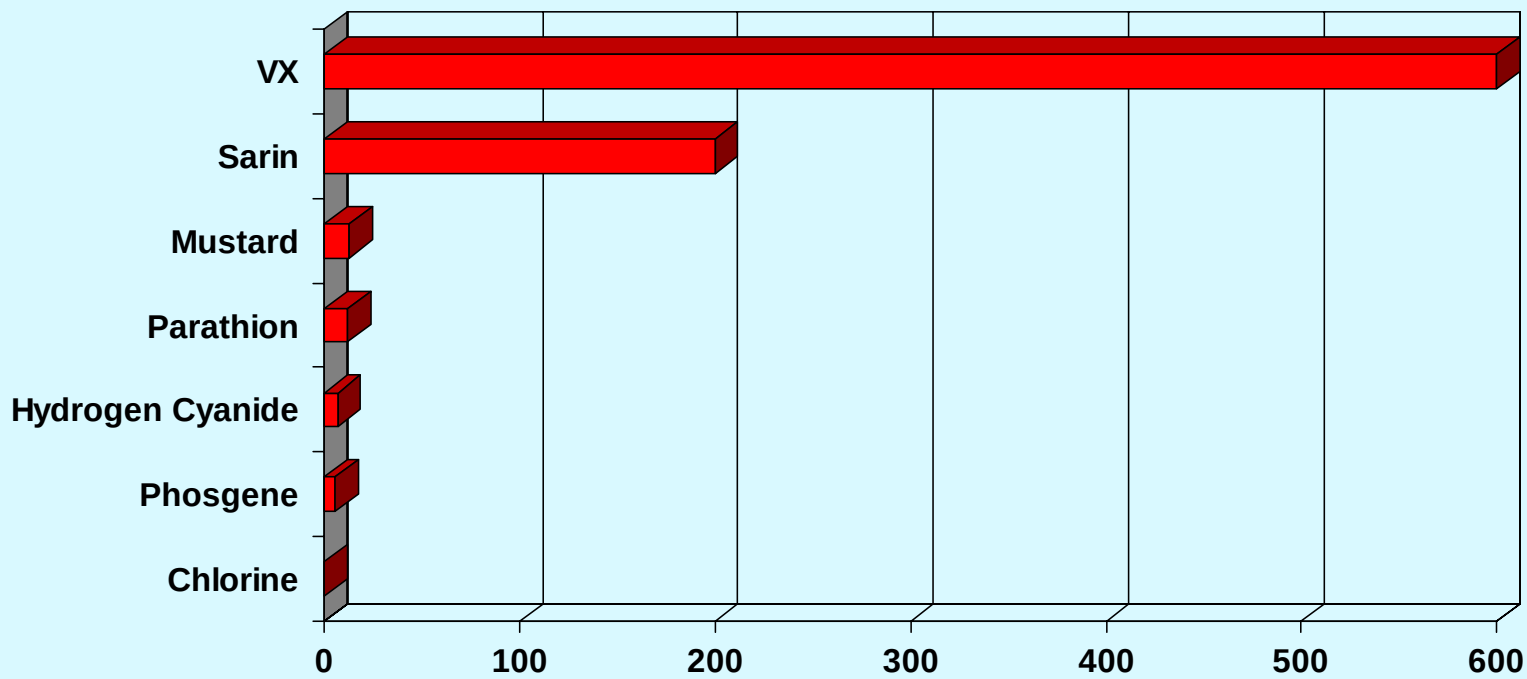
Comparative Toxicity



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How Much Sarin Does it Take?

Structure	Lethal Amount
Domed Stadium	107 kg (26 gals)
Movie Theater	1.2 kg (5 cups)
Auditorium	52 g (1/4 cup)
Conference Room (50-100 seating)	33 g (1 shot glass)

LD_{50} amounts for 1 minute exposure to Sarin aerosol

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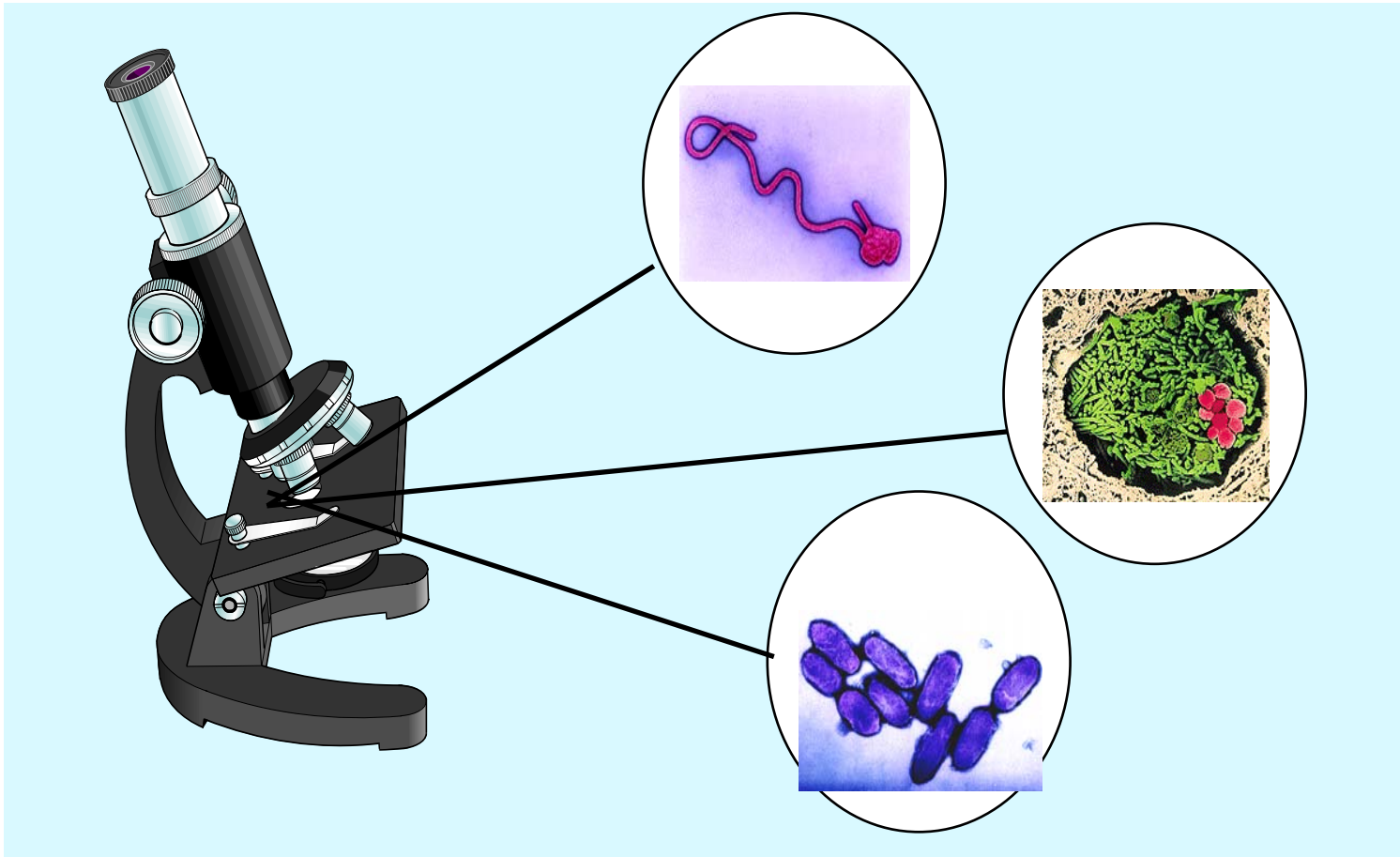
Chemical Agents Key Points

- Chemical agents are super toxic
- Relative toxicity: industrial chemicals < mustard < nerve
- Normal states are as a liquid or a vapor
- Inhalation hazard is of greatest concern

Biological Warfare Agents

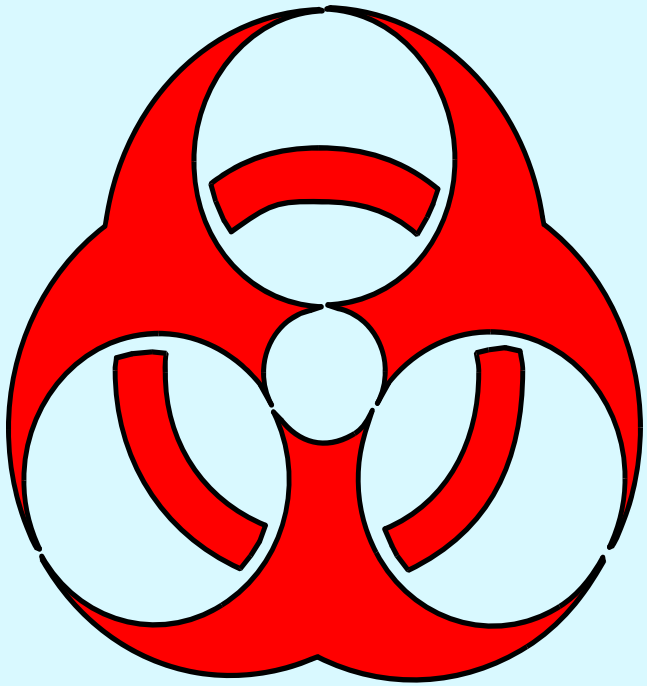


Classes of Biological Agents

Bacteria

Viruses

Toxins



FEMA 426 - Appendix C contains a CBR glossary and characteristics of biological agents

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Bacteria

	Anthrax	Plague
Incubation Period	1 to 6 days	2 to 3 days for pneumonic 2 to 10 days for bubonic
Contagious	NO	YES (pneumonic) NO (bubonic)
Signs and Symptoms	Chills, fever, nausea, swollen lymph nodes	Chills, high fever, headache, spitting up blood, shortness of breath
Protection	Standard Precautions	Standard Precautions and Droplet Precautions
Treatment	Antibiotics and vaccines	Antibiotics and vaccines

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Viruses

	Smallpox	Viral Hemorrhagic Fevers
Contagious	YES	YES
Signs and Symptoms	Fever, rigors, vomiting, headache, pustules	Fever, vomiting, diarrhea, mottled/blotchy skin
Protection	Standard Precautions + Droplet + Airborne + Contact Precautions	Standard Precautions + Droplet + Airborne + Contact Precautions
Treatment	Vaccine, supportive therapy	Vaccines available for some

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Toxins

	Neurotoxin (Botulinum)	Cytotoxin (Ricin)
Onset of Symptoms	1 to 3 days	4-8 hours after ingestion 12-24 hours after inhalation
Contagious	NO	NO
Signs and Symptoms	Weakness, dizziness, dry mouth and throat, blurred vision, paralysis	Chills, high fever, headache, spitting up blood, shortness of breath
Protection	Standard Precautions	Standard Precautions
Treatment	Supportive care, antitoxins, and vaccines	Supportive oxygenation and hydration

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Note: There are numerous naturally-occurring toxins. For our purposes, we will group them into two categories.

Biological Agents Key Points

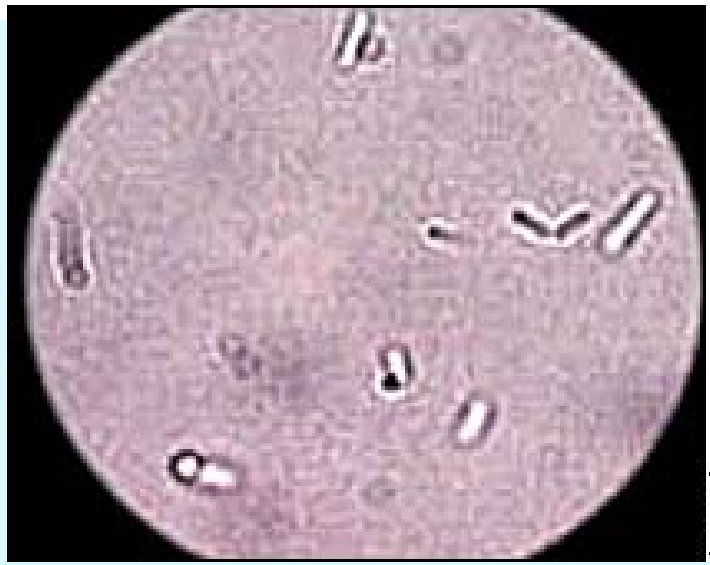
Onset of symptoms

Potentially contagious

Signs and symptoms

Protection

Treatment



Biological Agent Categories

Some Biological agent(s)	Disease
Category A	**Category A**
• Variola major	• Smallpox
• Bacillus anthracis	• Anthrax
• Yersinia pestis	• Plague
• Clostridium botulinum	• Botulism
• Ebola, Marburg	• Tularemia
	• Viral hemorrhagic fevers
Category B	**Category B**
• Coxiella burnetii	• Q Fever
• Brucella spp.	• Brucellosis
• Burkholderia mallei	• Glanders
• Burkholderia pseudomallei	• Melioidosis
• Toxins	• Psittacosis
• Food/Water safety threats	• Ricin toxin
	• Typhus
Category C	• Cholera
• Emerging threat agents	• Shigellosis

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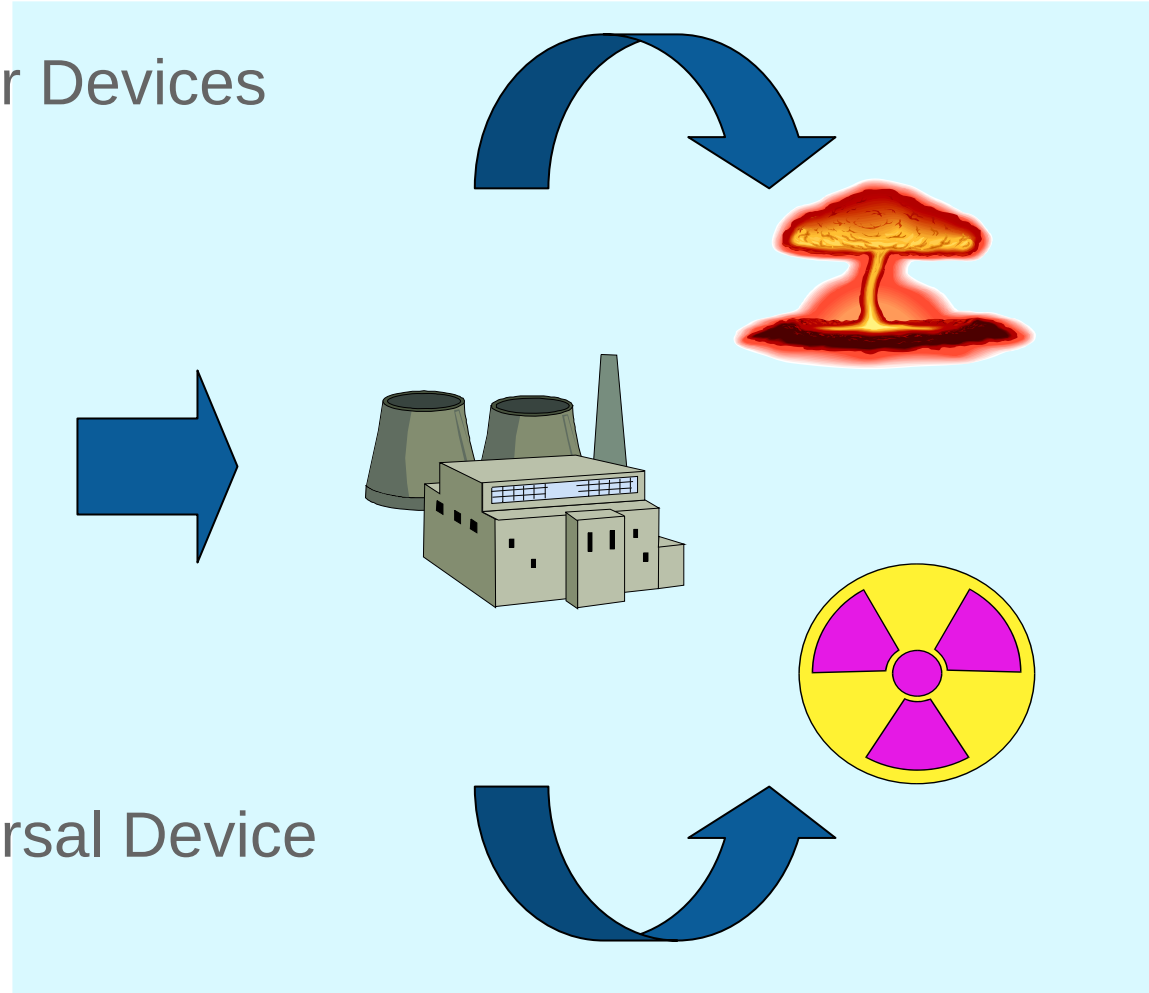
Nuclear/Radiological Materials

Improvised Nuclear Devices

Nuclear Plants

Radiological Dispersal Device



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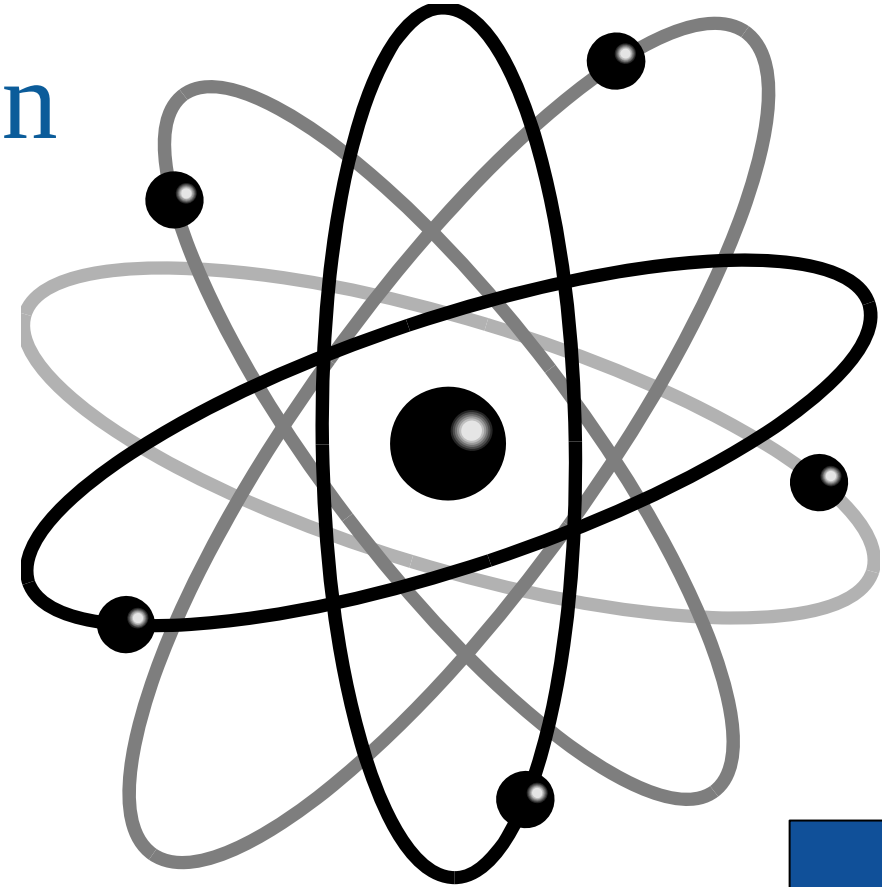
Ionizing Radiation

Alpha particles

Beta particles

Gamma rays

Neutrons



There are also non-ionizing types of radiation – fluorescent lights, lasers, and microwaves. In these examples, the radiation can cause burns, but it does not cause molecular change or ionization

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Common Radiation Exposures

Average annual exposure	360 mrem per year
Chest x-ray	10 to 30 mrem
Flight	0.5 mrem every hour
Smoking 1.5 packs per day	16,000 mrem per year
Mild radiation sickness*	200,000 mrem
Lethal dose*	450,000 mrem

Chronic

Acute

*** single acute exposure**

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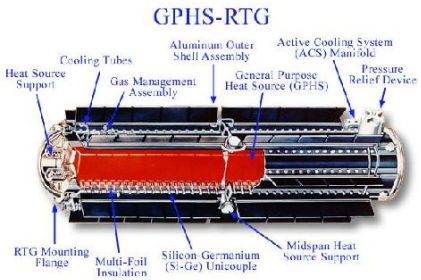
Health Hazards in an Incident

- Exposure to radiation source (external)
- Contamination (possible internal and/or external)

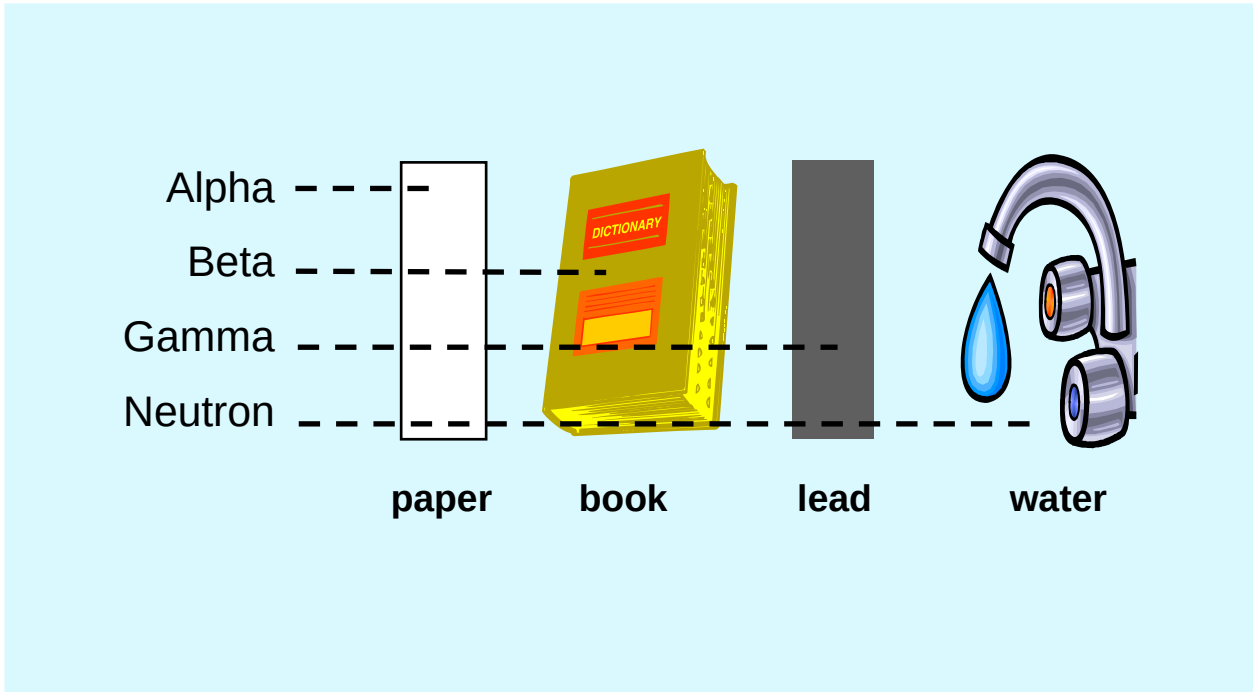


Protection from Radiation Exposure

Time

Distance

Shielding



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CBR Detection

Radiological	✓
Chemical	✓
Biological	?

SOURCE: BAE SYSTEMS

SOURCE: BRUKER DALTRONICS

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CBR Incident Indicators

Indicator	Chemical	Biological	Radiological
Dead Animals	✓		✓
Lack of Insect life	✓		
Physical Symptoms	✓	✓	✓
Mass Casualties	✓		✓
Unusual Liquids	✓		
Unexplained Odors	✓		
Unusual Metal Debris/Canisters	✓	✓	✓
Heat Emitting or Glowing			✓
Spray Mechanisms	✓	✓	

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Chemical Incident Indicators (1)

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.

Chemical agents have a rapid onset of symptoms

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FEMA 426, Table 5-2: Indicators of a Possible Chemical Incident, p. 5-34

Chemical Incident Indicators (2)

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, brushes, food crops, and/or lawns that are dead, discolored, or withered. (Not current drought.)
Unexplained odors	Smells may range from fruity to flowery to sharp/pungent to garlic/horseradish like to bitter almond/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 clouds/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.)

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FEMA 426, Table 5-2: Indicators of a Possible Chemical Incident, p. 5-34

Biological Incident Indicators

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.

Biological agents will typically have a more delayed effect

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FEMA 426, Table 5-3: Indicators of Possible Biological Incident, p. 5-35

Radiological Incident Indicators

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.

Radiological agents will typically have a more delayed effect

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FEMA 426, Table 5-4: Indicators of a Possible Radiological Incident, p. 5-36

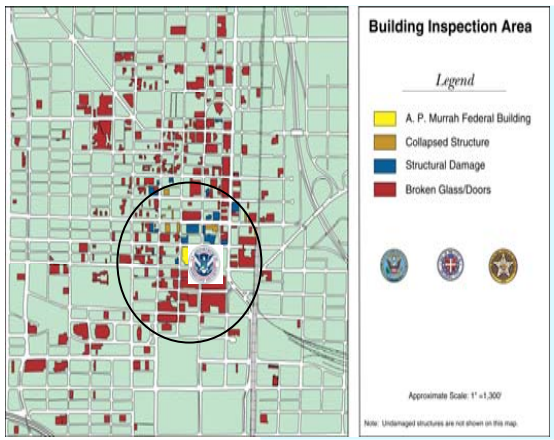
CBR Protection Strategies

Protective Actions:

- Evacuation
- Sheltering in Place
- Personal Protective Equipment
- Air Filtration, Pressurization, and Ultraviolet Light
- Exhausting and Purging

Evacuation

- Determine airborne hazard source -- internal or external
- Determine if evacuation will make things better or worse
- Assembly should be upwind, at least 1,000 feet away, and three different locations (A, B, C plan)
- In most cases, existing plans for fire evacuation apply – follow through - exercise



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Sheltering in Place

A building can provide substantial protection against agents released outside if uptake of contaminated air can be halted or reduced and/or if uptake of fresh/filtered air can be increased.

The amount of protection varies with:

- How tight the building is
- Level of exposure (dose x time)
- Purging or period of occupancy
- Natural filtering

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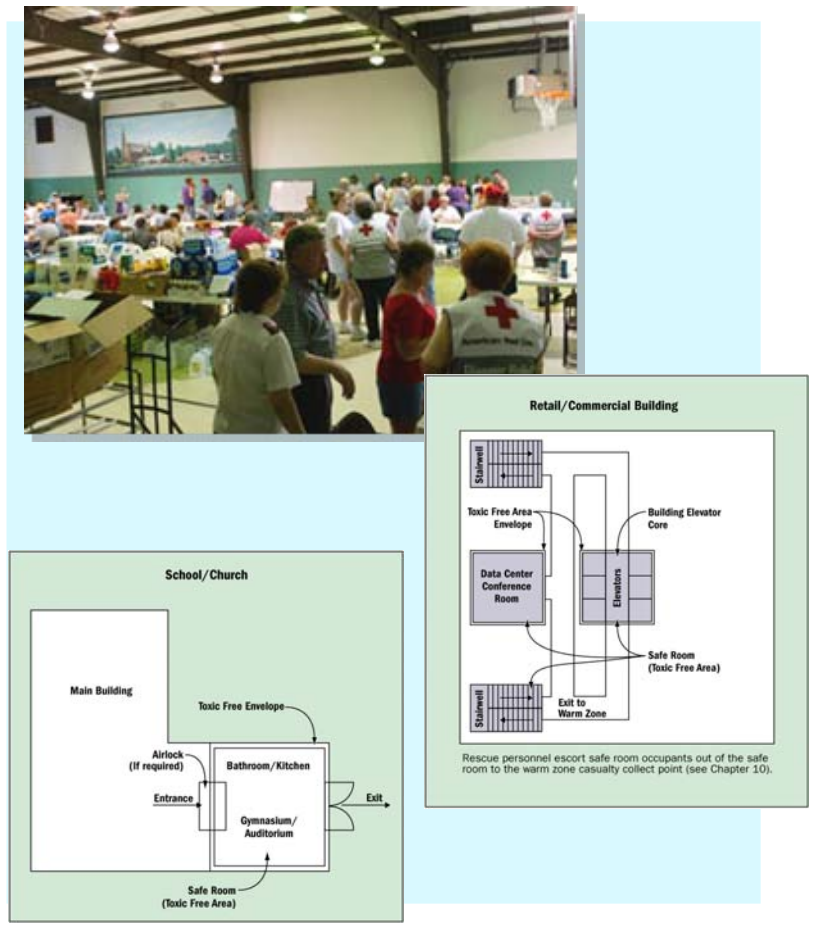
Sheltering in Place

Sheltering Plan should:

- Identify all air handling equipment to deactivate
- Identify cracks, seams, joints, and doors to seal (with method)
- Preposition needed supplies
- Identify safe rooms/safe havens
- Identify procedures for purging or airing out building
- Identify procedures for voluntary occupant participation
- Maintain comms - TV or radio



FEMA 453, Multihazard Shelter (Safe Havens) Design

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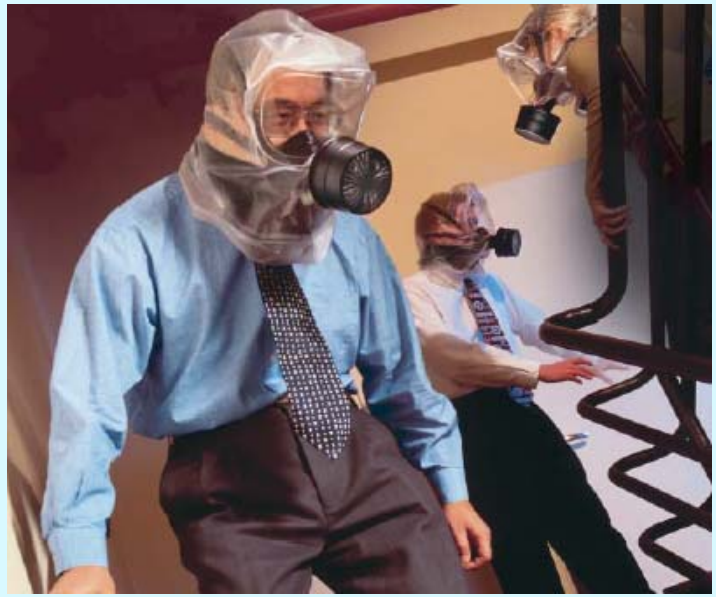
Personal Protective Equipment

SOURCE: BARDAS CHILD PROTECTIVE WRAP (ISRAEL)



SOURCE: MINE SAFETY APPLIANCES COMPANY (USA)

SOURCE: BROOKDALE INTERNATIONAL SYSTEMS INC (CANADA)

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Aftermath of Tragic Events


NMRT decontamination corridor.

Assembly should be to the upwind side of the building at least 1,000 feet away since any airborne hazard escaping the building during an internal release will be carried downwind.

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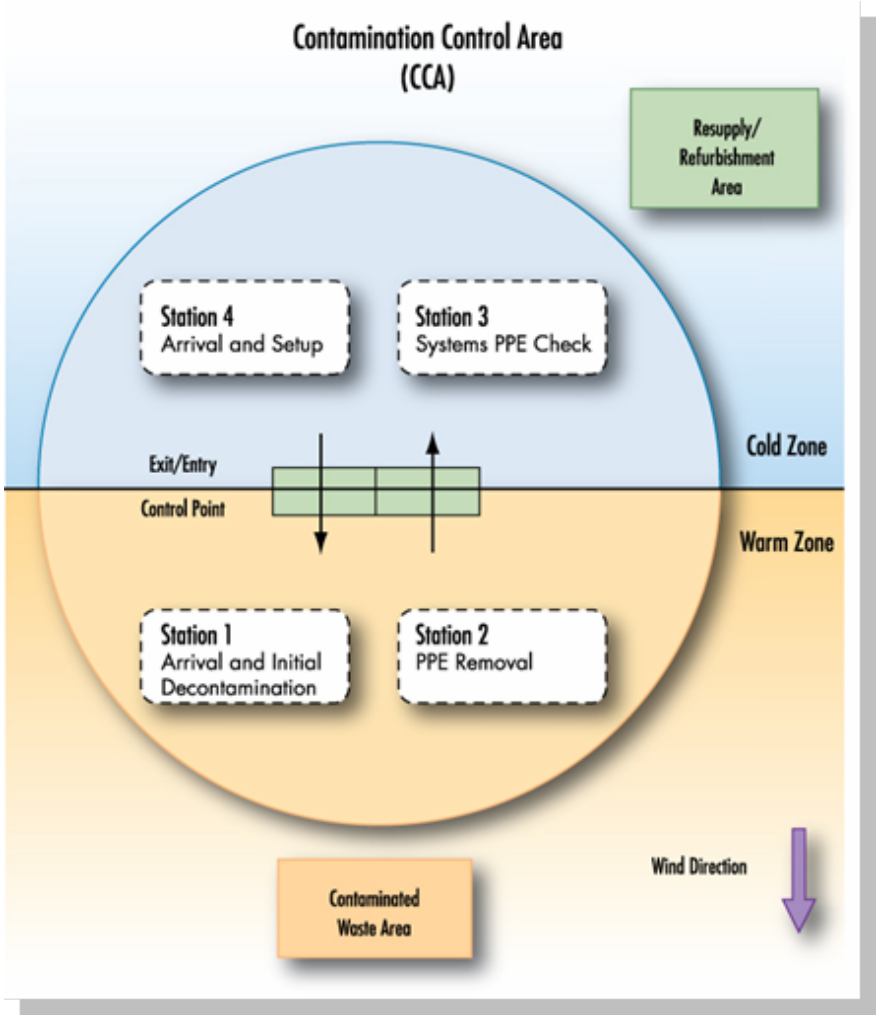
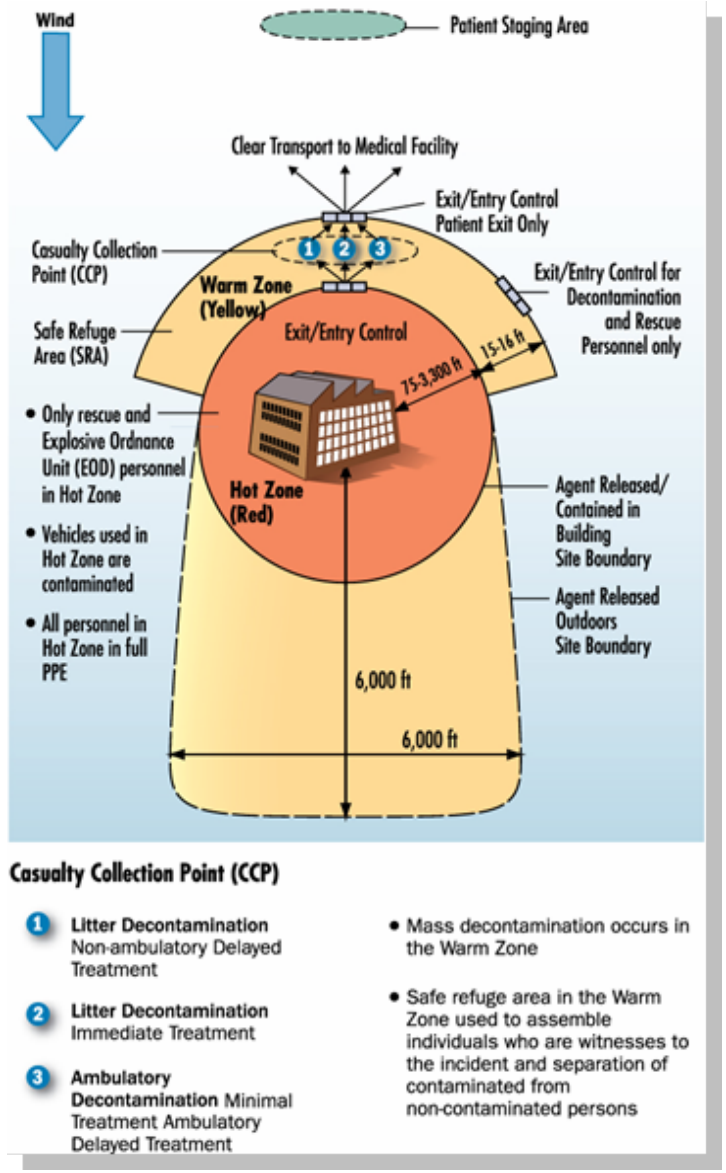
Casualty Collection Point





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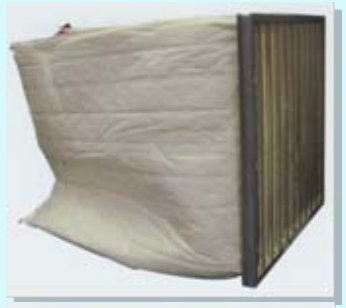
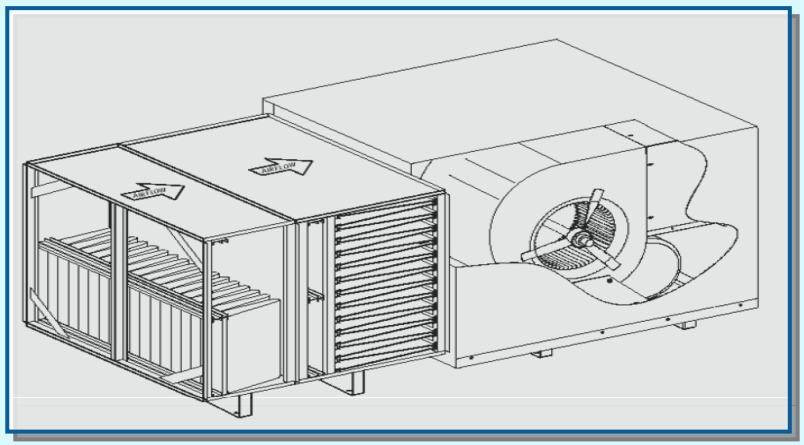
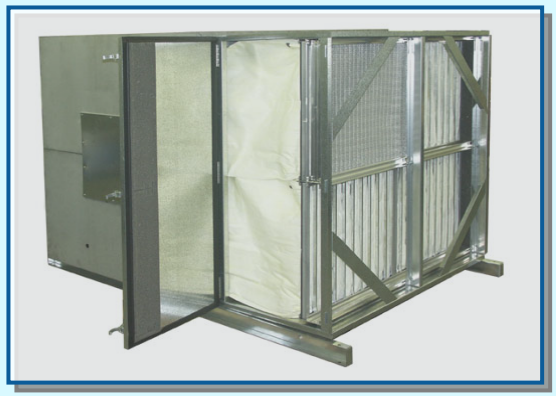
FEMA 453, Figure 1-18, p. 1-57, and Figure 1-13, p. 1-52

Air Filtration and Pressurization

- Requires modifications to HVAC and electrical systems – significant initial and life-cycle costs
- Introduces filtered air at a rate sufficient to produce an overpressure and create an outward flow through leaks and cracks







SOURCE: TRION INCORPORATED

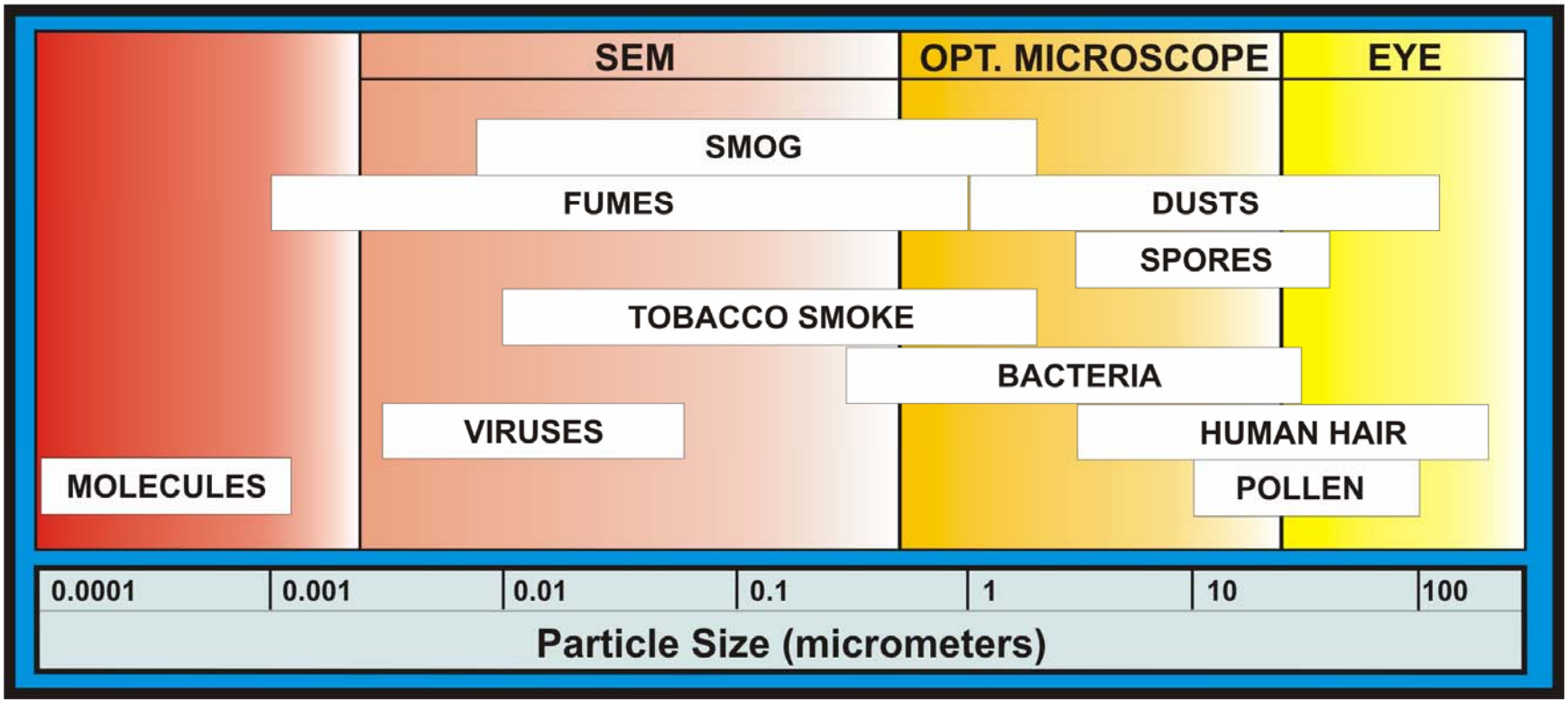
FEMA 426, Figures 5-5 and 5-12: Bag Filter and HEPA Filter; Commercial Air Filtration Unit, p. 5-12 and 5-22

Air Filtration and Cleaning

Two Types of Collection Systems:

- Particulate air filtration
  - Principles of collection
  - Types of particulate filters
  - Filter testing and efficiency ratings
- Gas-phase air filtration
  - Principles of collection
  - Types of gas-phase filters

Air Contaminant Sizes



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Various Filter Types

HEPA Filters

SOURCE: FLANDERS CORPORATION

Pleated Panel Filters

SOURCE: AMERICAN FILTER

Carbon Filters

SOURCE: FLANDERS CORPORATION

FEMA 426, Figure 5-9: Charcoal Filter Beds (center), p. 5-17

ASHRAE Standards

ASHRAE 52.2				ASHRAE 52.1		Particle Size Range, µm	Applications
MERV	Particle Size Range			Test			
	3 to 10 µm	1 to 3 µm	.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%		

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FEMA 426, Table 5-1: Comparison of ASHRAE Standards 52.1 and 52.2, p. 5-12

ASHRAE Standards

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, Chembio, Viruses
18	-	-	≥ 99.99%	-	-		
19	-	-	≥ 99.999%	-	-		
20	-	-	≥ 99.9999%	-	-		

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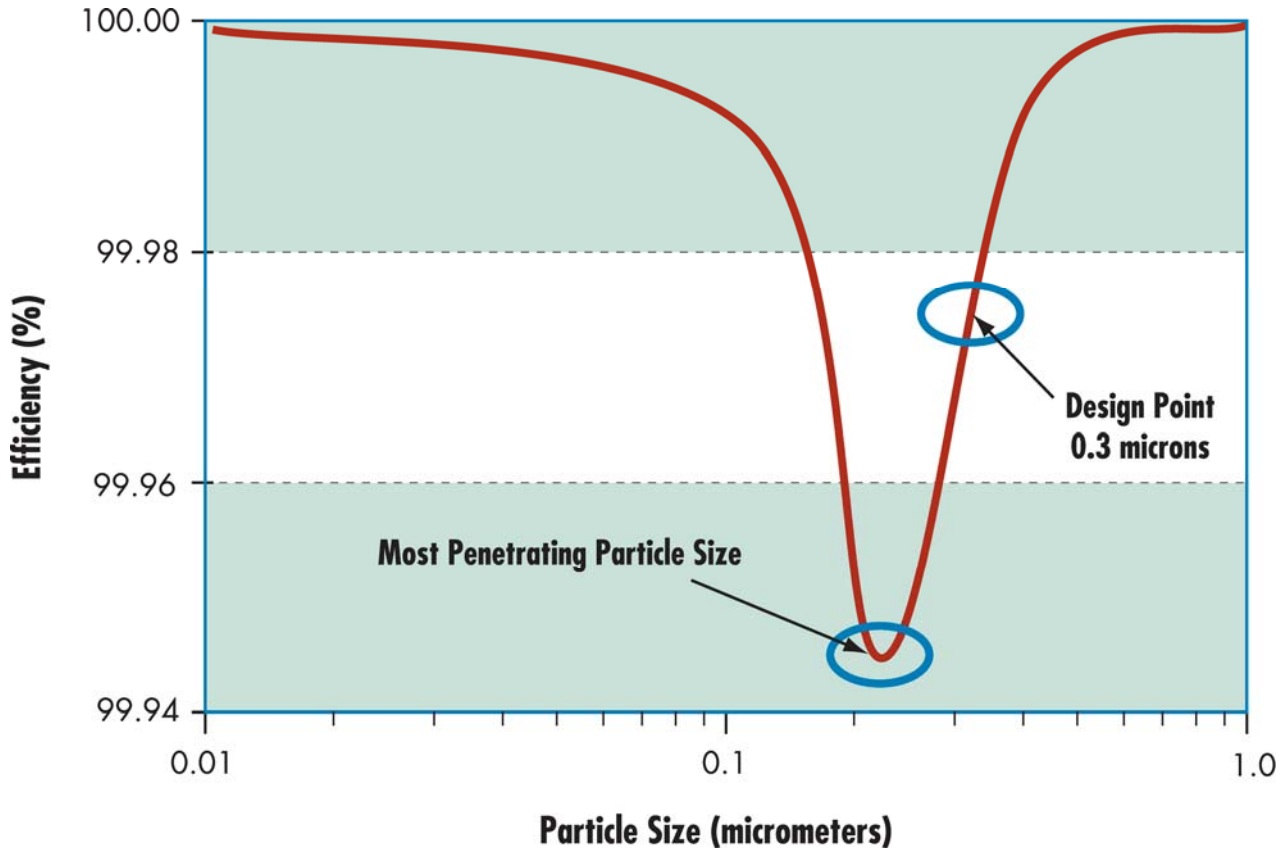
FEMA 426, Table 5-1: Comparison of ASHRAE Standards 52.1 and 52.2, p. 5-12

Typical Performance of a HEPA Filter



FEMA 426, Figure 5-7: Typical HEPA Filter Performance p. 5-14

Inside Versus Outside Releases

Outside Release

- Keep people inside building
- Reduce indoor/outdoor air exchange – close dampers
- Shut off air handling systems and equipment that moves air – HVAC, exhausts, combustion, computers, elevators
- Close all windows and doors
- Once the outdoor hazard has dissipated
  - Open all doors and windows
  - Turn on all fans, including purging systems

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Inside Versus Outside Releases

Inside Release

- Turn off all air handling equipment if no special stand-alone systems installed
- If special systems installed, i.e. mailroom
  - Place air handling system on full (or 100% outside air) to pressurize the space around release room
  - Turn off all air handling supplying release room
- Consider activating fire sprinklers in release room if toxic chemicals involved
- Evaluate evacuation routes for contamination
- Evacuate building in accordance with emergency plan

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Exhausting and Purging

Basic Principles:

- Use ventilation and smoke/purge fans to remove airborne hazards
  - Use primarily after an external release plume has passed
  - Selectively use for internal release – may spread contamination further
- Purging should be carefully applied
  - Primarily when agent has spread throughout building

HVAC System Upgrade Issues

- What is the threat? Toxic Industrial Chemicals, particulate, gaseous, chemical, biological?
- How clean does the air need to be and what is the associated cost?
- What is the current system capacity?
- Is there filter bypass and how significant is air infiltration into the building envelope?
- Will improved indoor air quality offset upgrade costs?
- Is system maintenance addressed?

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Economic Issues to Consider

Initial Costs

- Filters, housing, blowers
- Factors including flow rate, contaminant concentration

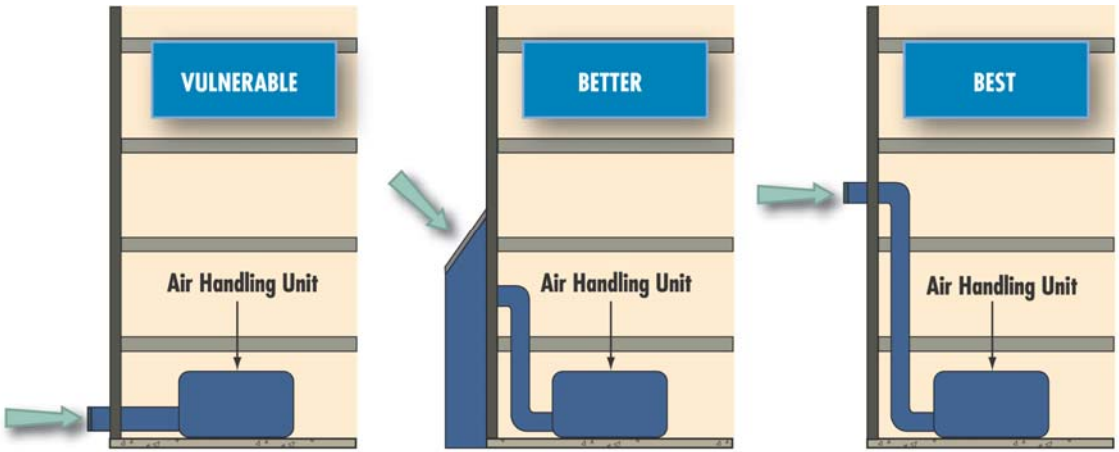
Operating Costs

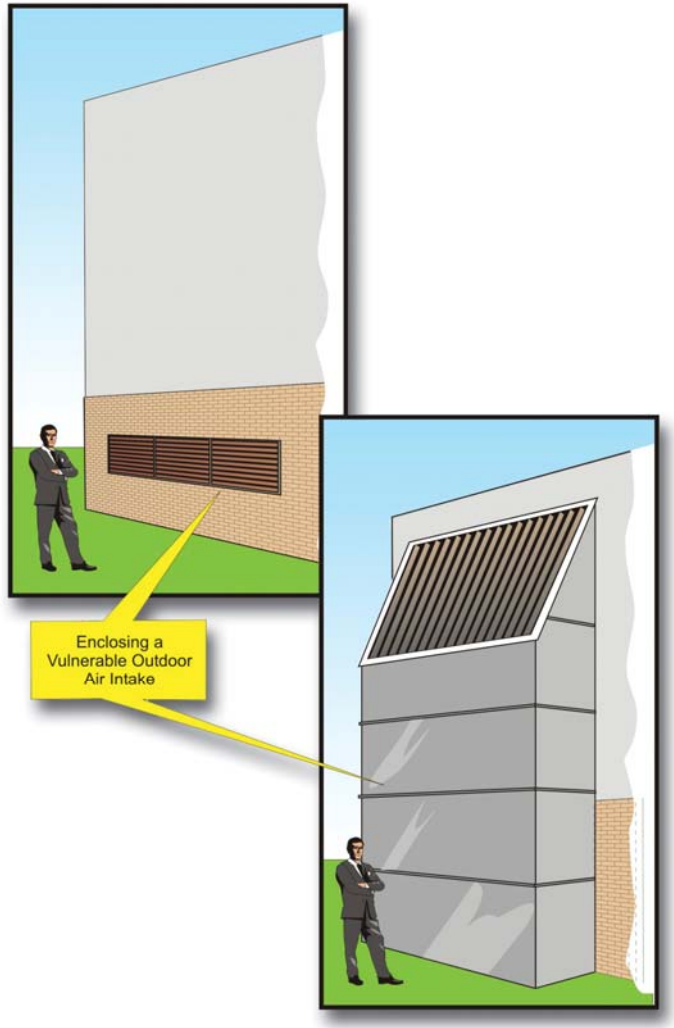
- Maintenance, replacement filters, utilities, waste disposal

Replacement Costs

- Filter life (factors include continued concentration and particle size distribution, flow rates, etc.)

Access to Outdoor Intakes

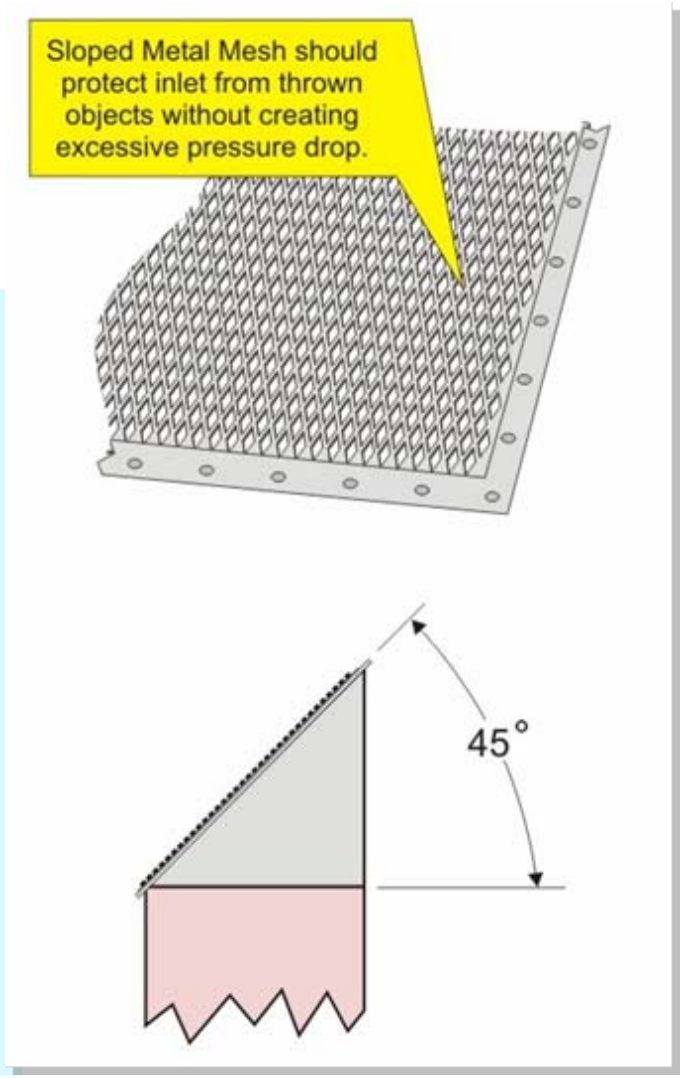




FEMA 426, Figure 3-8, Example of Protecting Outdoor Air Intakes, p. 3-36 and Figure 3-11, Example of Enclosing Existing Vulnerable Air Intake, p.3-38

Extension Design Recommendations

- Lowest edge as high as possible (> 12ft)
- Sloped intake (min. 45° recommended)
- Metal mesh protecting intake



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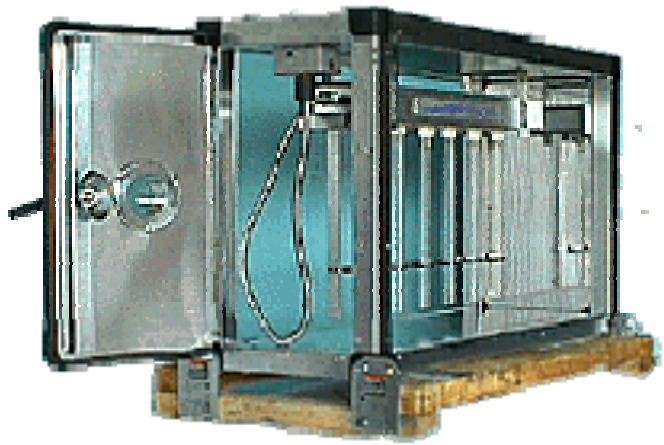
From CDC/NIOSH 2002-139, Guidance for Protecting Building Environments from Airborne Chemical, Biological, or Radiological Attacks, p. 21

Ultraviolet Germicidal Irradiation

All viruses and almost all bacteria (excluding spores) are vulnerable to moderate levels of UVGI exposure



UV lamps resemble ordinary fluorescent lamps, but are designed to emit germicidal UV

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FEMA 426, Figure 5-10: UVGI Array with Reflective Surfaces, p. 5-19

URV AND UVGI INFORMATION

URV Average Intensities and Doses			
URV (UVGI Rating Value)	Average Intensity $\mu W/cm^2$	Dose at t (time) = 0.5 sec $\mu W/s/cm^2$	TB (Tuberculosis) Kill Rate %
9	250	125	23.4
10	500	250	41.3
11	1,000	500	65.5
12	1,500	750	79.8
13	2,000	1,000	88.1
14	3,000	1,500	95.9

URV = **U**VGI **R**ating **V**alue

UVGI = **U**ltra**v**iolet
Germicidal
Irradiation

Simulation Results for Air Intake Release			
Predicted Performance	Anthrax	Smallpox	TB Bacilli
URV 11 - UVGI Removal Rate%	8.0	53.4	65.6
MERV 11 Filter Removal %	56.7	32.3	14.1
Combined Removal Rate %	60.2	68.5	70.4
Baseline Casualties (release over 8 hour period) %	99.0	99.0	99.0
Casualties with Filters and UVGI %	1.0	1.5	1.5

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From *"Immune Building Systems Technology", Kowalski 2003*

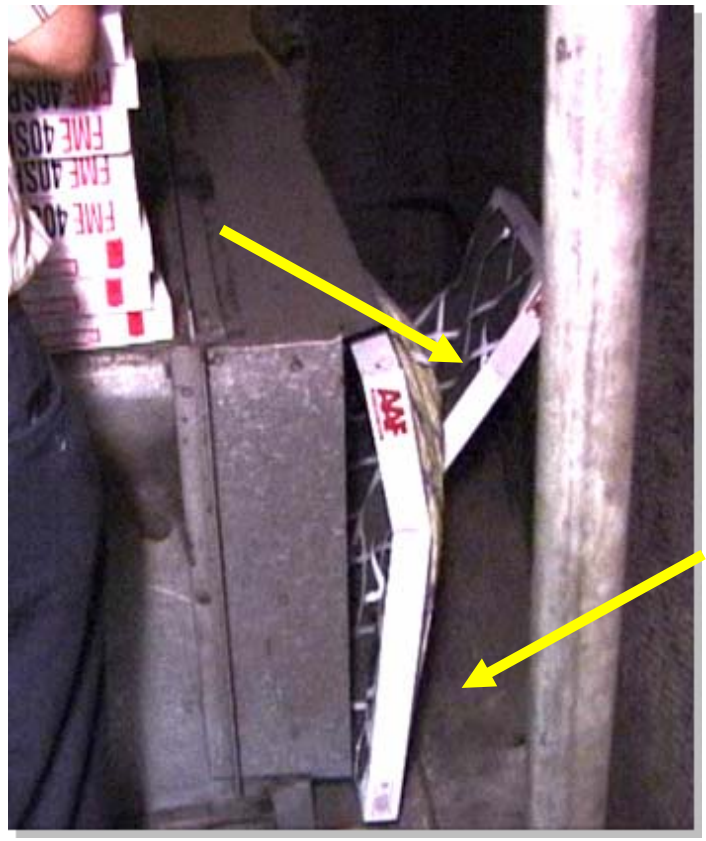
Infiltration and Bypass

Infiltration

- Building envelope tightness and ventilation control are critical

Bypass

- Filters should be airtight
- Check gaskets and seals
- Periodically check



Things Not to Do

- Outdoor air intakes should not be permanently sealed.
- HVAC systems (includes filter upgrades) should not be modified without understanding the effects on building systems or occupants.
- Fire protection and life safety systems should only be modified after careful analysis and review.

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Things to Do

- Have a current emergency plan that addresses CBR concerns
  - Exercise plan
  - Revise plan based upon lessons learned
- Understand your HVAC building vulnerabilities
- Conduct periodic walk-through of the system for evidence of irregularities or tampering
- Recognize that there are fundamental differences among various CBR events

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Summary

- CBR threats are real and growing.
- Industrial chemicals are readily available.
- Military chemicals require specialty expertise.
- Most buildings provide a reasonable level of protection.
- Inside versus outside building release determines evacuation and other reaction decisions.
- Develop an emergency plan and ensure it works.

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Unit VIII Case Study Activity

Chemical, Biological, and Radiological (CBR) Measures

Background

Purpose of activity: check on learning about the nature of chemical, biological, and radiological agents

Requirements

Refer to Case Study and FEMA 426

Answer worksheet questions

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