The First Responder's Pocket Guide to Radiation Incidents

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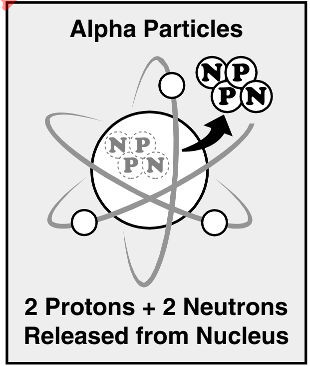
Chapter 1

Introduction to Radiation

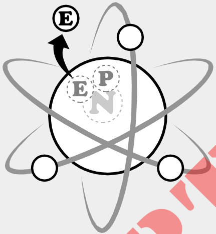
What is radiation?
Why is it harmful?
This chapter provides background information to help readers understand the chapters that follow.

Alpha particles are subatomic particles made of two protons and two neutrons released from the nucleus of an atom. They are relatively large particles that travel only a couple inches in air. Alpha particles contain a lot of energy, but have very low penetrating power. They're stopped by shielding as light as a sheet of paper and cannot penetrate intact skin; thus they're not a serious external hazard. But if alpha emitters (radioactive materials that emit alpha particles) enter the body through inhalation, ingestion, or contamination of an open wound, they will deposit their ionizing energy in the adjacent tissues.



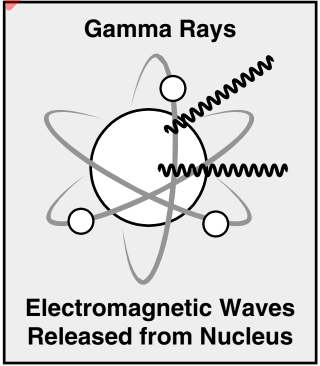
An excess neutron in the nucleus can transform into a proton and electron. The electron is then ejected as a **beta particle**. These relatively small particles can travel several feet to several yards in air. They vary in energy level. Those with the highest energy level can penetrate about a half-inch through intact skin. External exposure to beta particles can produce burns to the skin. But the greatest danger is from internal exposure to beta emitters that are inhaled, ingested, absorbed, or injected into the body. It takes heavier shielding, such as aluminum, wood, or plastic, to stop beta radiation.

Beta Particles



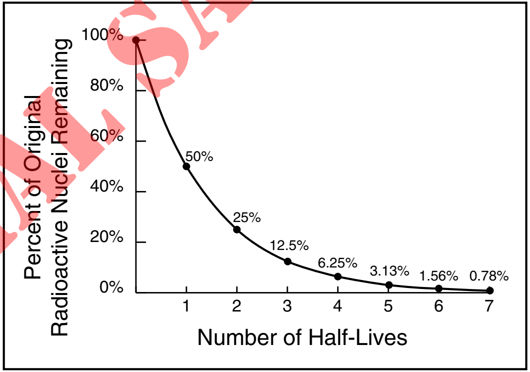
Electrons Created and Released from Nucleus

Gamma rays are high-energy electromagnetic waves generated in the nucleus of an atom. Gamma radiation travels at the speed of light and has strong penetrating power, able to travel considerable distances and through skin, PPE, or other objects.



Although gamma emitters (radioisotopes that emit gamma radiation) can be inhaled, ingested, or absorbed through open wounds, most exposures to gamma rays are from an external source. Dense shielding, such as lead or concrete, is required to stop gamma radiation. Gamma emitters often emit alpha or beta particles also.

Half-life is the measure of how long it takes for one half of a radioactive material's atoms to decay. Half-life is reflected by a 50% drop in energy level (for example, from 10 mR/hr to 5 mR/hr as seen on a survey meter). The half-life of a radioisotope is constant and independent of the sample size. As a rule of thumb, a radioactive isotope decreases to less than 1% of its original energy level after seven half-lives.



Half-lives can vary from less than a second to thousands or millions of years. For example, carbon-14, the material used in carbon dating, has a half-life of 5730 years. Americium-241, used in ionization smoke detectors, has a half-life of 432.2 years. The half-life of iodine-131, used to treat thyroid cancer, is 8.04 days. Technetium-99m, the radioisotope most widely used in medicine, has a half-life of 6 hours. The following are other examples.

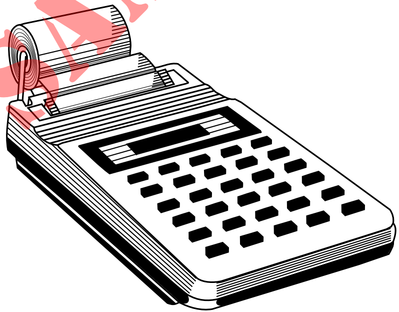
Radionuclide	Half-Life	Radionuclide	Half-Life
Californium-252	2.6 years	Nickel-63	100 years
Cesium-137	30 years	Radium-226	1599 years
Cobalt-60	5.3 years	Sulphur-35	87 days
Gallium-67	3.3 days	Technetium-99	213,000 years
Iodine-123	13 hours	Uranium-235	704,000,000 years

Half-life is significant in determining how long an area must be sealed off and whether the incident can be allowed to self-mitigate. If a material's half-life is only a few hours or days, it may be best to simply seal off the site until the hazard is no longer present. Conversely, if the half-life is several years, it will probably be necessary to bring in a cleanup company to mitigate the hazard.

Chapter 2

Exposure Limits and Units of Measure

Radiation is *not* measured in parts per million or percent by volume in air as are most hazardous materials. The units of measure for radioactive materials are very different.



Roentgen (R) is the unit of measure that identifies the amount of radiation (energy) produced by gamma rays and x-rays. It is a measure of the *exposure (dose) rate*—the ionization in air. Detectors commonly measure gamma radiation in roentgens, milliroentgens, or microroentgens *per hour* (R/hr, mR/hr, or μR/hr). (The prefixes are explained on page 60.) What this means is that a person would have to be in that environment for 60 minutes to be exposed to the amount of radiation displayed on the detector. (The relation between time and exposure is explained in more detail on page 56.)

Roentgen
Measures
Gamma and
X-Ray Radiation
(Energy) in Air
— Dose Rate

Rad (radiation absorbed dose) describes radiation energy absorbed by exposed matter (living or not). The international equivalent of rad is **gray (Gy)**. However, 1 gray equals 100 rads.

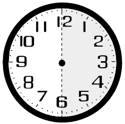
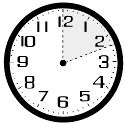
Rem (roentgen equivalent man) and millirem (mrem) are used to measure energy absorbed by *living* tissue (the *dose* received). They reflect the biological damage done by an absorbed dose of radiation. (One rem equals 1000 millirems.) The international equivalent of rem is **sievert (Sv)**. However, 1 sievert equals 100 rems.

Rad and **Gray** Measure Energy Absorbed By Any Matter (Living or Not)

Rem and **Sievert** Measure Energy Absorbed By Living Tissue (Dose) and Reflect Biological Damage

Understanding the relation between time and exposure can help you stay within the EPA exposure limits identified on page 47. For example, if you needed to rescue someone who was trapped in a 50-R/hr atmosphere, you could stay up to 30 minutes without going over the 25-rem limit to save a life. Or you could use multiple teams, limiting each to 12 minutes to keep everyone's exposure at or below 10 rems.

Obviously, it's essential to have someone keep track of time during this operation and to document the information for employee exposure records.

Dose Rate: 50 R/hr	Dose Rate: 50 R/hr
	
Exposure: 25 rems	Exposure: 10 rems

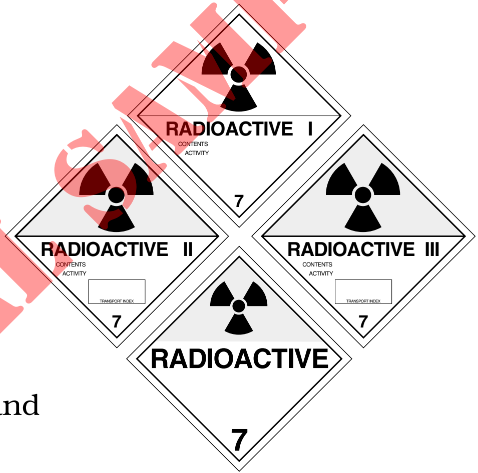
The **Incident Stay Time Table** below is one tool to help you calculate how long you can safely remain in the hot zone.

Dose Rate	Time to Receive Maximum Dose		
	5 rem	10 rem	25 rem
2 mR/hr	104 days	208 days	520 days
5 mR/hr	41.6 days	83.3 days	208 days
10 mR/hr	20.8 days	41.6 days	104 days
25 mR/hr	8.3 days	16.6 days	41.6 days
50 mR/hr	4.1 days	8.3 days	20.8 days
0.5 R/hr	10 hours	20 hours	50 hours
1 R/hr	5 hours	10 hours	25 hours
20 R/hr	15 minutes	30 minutes	75 minutes
50 R/hr	6 minutes	12 minutes	30 minutes
100 R/hr	3 minutes	6 minutes	15 minutes

Chapter 3

Labels, Placards, and Packages

Later in the book, we'll explore radiation monitoring. However, you can often estimate exposure potential with an understanding of signage and packaging.



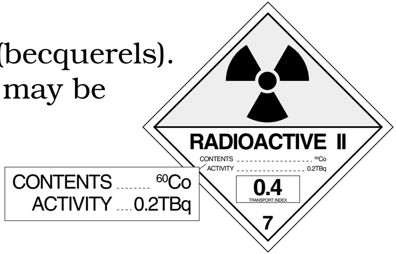
The designation of Radioactive I, II, or III is based on radiation level (dose rate) as measured both at the surface of the package and at 1 meter (3 feet) away. Shown below are the maximum limits associated with each label—the maximum exposure rate one should detect *above normal background levels*. (The units of radiation measure are defined on page 50. Background radiation is addressed on pages 153 through 155.)

Label	At Package Surface	At 1 Meter (3 Feet) from Package
I	0.5 mR/hr	None
II	50 mR/hr	1 mR/hr
III	200 mR/hr	10 mR/hr

Labels also identify the radioisotope (contents) and its rate of decay (activity).

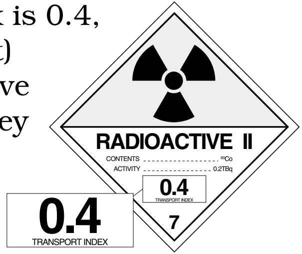
The **contents** are normally identified by name, but they may be identified by authorized symbols instead (e.g., ^{60}Co versus Cobalt-60). Low-specific activity (LSA-I) materials may be identified with the term *LSA-I* instead of the actual radionuclide.

Activity is expressed in SI units (becquerels). English units of measure (curies) may be included in parentheses following the SI units. (In some cases, the weight of fissile materials may be used in place of SI units.)



The Radioactive II and III labels contain a **transportation index (TI)**. (The transportation index is also indicated on shipping papers.) This number identifies the maximum radiation level (measured in mR/hr) at 1 meter (3 feet) from any surface of an undamaged package.

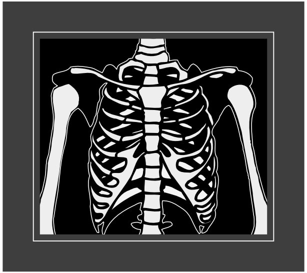
For example, if the transportation index is 0.4, the radiation intensity at 1 meter (3 feet) should be no more than 0.4 mR/hr above normal background levels. If your survey meter is reading something higher, you should suspect that the package has been breached.



Chapter 4

Health Effects of Radiation Exposure

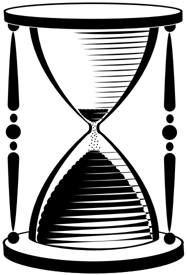
Everything we've covered so far leads us to the question, How does radiation exposure affect us?



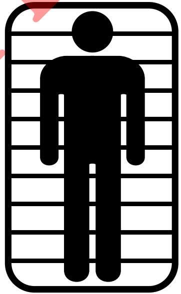
A person can be exposed* to radiation without being *contaminated. A common example is when receiving a medical x-ray. Exposure to radiation can cause tissue damage, but it won't make an exposed person radioactive. That person poses no threat to others.

However, a person who has a radioactive substance on his or her body is **externally contaminated**. He or she acts as a radioactive source and can both expose and contaminate other people. It's safest to assume that victims are contaminated until proven otherwise.

The speed with which initial signs and symptoms appear increases with exposure level. Onset of nausea and vomiting—the earliest clinical signs of acute radiation sickness—usually takes several hours. So **when health effects are observed right after an incident, one should first suspect other causes**, such as traumatic injuries, exposure to other hazardous materials, or other hazardous properties (e.g., corrosivity or toxicity) of the radioactive materials. Even anxiety over a *presumed* exposure can cause nausea and vomiting. However, if nausea and vomiting occur shortly after exposure, one must also consider the possibility that patients received a high absorbed dose of radiation.



Health effects vary depending on the type of radiation, how much of the body was exposed, the depth of penetration, the dosage received, and whether the exposure is from a single event or multiple events. (Multiple exposures increase the risk of cancer and tax the body's ability to repair itself.) Health effects also vary based on individual factors, such as age and state of health. **The following health effects apply to acute whole body exposures**:



- There may be mild symptoms with doses as low as **30 rems** (0.3 Sv), but most people won't develop what is considered "radiation sickness" at less than **70 to 100 rems** (0.7 to 1.0 Sv).

- Whole body exposures **above 70 to 100 rems** (0.7 to 1.0 Sv) may cause nausea and vomiting for 1 to 2 days and a temporary drop in the production of new blood cells.

- **As the exposure increases**, so do the signs and symptoms of radiation sickness. Initial effects may include nausea, vomiting, diarrhea, dizziness, fatigue, headache, and loss of appetite. Higher doses may also cause fever, sweating, and difficulty breathing.

Remember: 1 rem = 1000 millirems

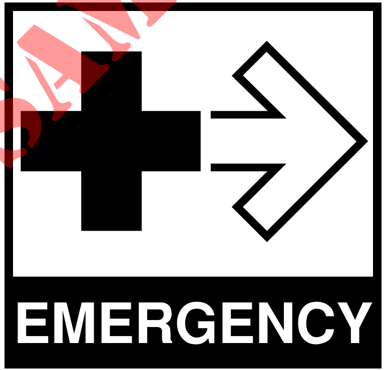
- **Above 350 rems** (3.5 Sv), the initial effects will be followed by a period of apparent wellness. But usually within 2 to 3 weeks, patients will become sick again and experience infection, electrolyte imbalance, diarrhea, bleeding, cardiovascular problems, and sometimes lapses in consciousness. Medical care is required.

- The experts don't agree on a precise number, but a whole body exposure in the range of **250 to 500 rems** (2.5 to 5.0 Sv) **is considered the LD_{50}/60 days**, meaning that 50% of patients exposed to this level of radiation will die within 60 days if untreated. However, all can survive with proper medical attention.

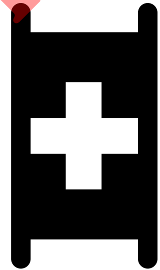
Chapter 5

Decontamination and Patient Care

Decon and patient care at radiation incidents is similar to that required for other chemical exposures. So this chapter will focus on the highlights and differences rather than cover the topic in depth.



Rescue is a higher priority than measuring radiation levels. And by using time, distance, and shielding to minimize exposure to radiation, you should be able to safely effect a rescue without waiting for a hazmat team or radiation experts.



However, there may be other significant hazards that would make it unsafe for you to perform a rescue. As with any other medical emergency, **your first priority is to ensure your own safety**. Don't go into the hot zone unless it's safe to do so. If patients can walk, direct them to move to a safe refuge area. Otherwise, wait until they can be rescued by appropriate personnel.

Once patients have been thoroughly decontaminated, they present no risk of secondary contamination; thus **standard universal precautions** (barriers, handwashing, and precautions to prevent injuries) **are adequate**.

However, if patients have not been decontaminated, wear clothing that will protect against inhalation, ingestion, and skin contact with radioactive materials. This includes a long-sleeve uniform, gloves, hood or hair cover, eye protection, shoe covers, and a face mask (N95 HEPA filter or equivalent).

Pay particular attention to areas where contamination is most likely and areas that provide a route of entry into the body:

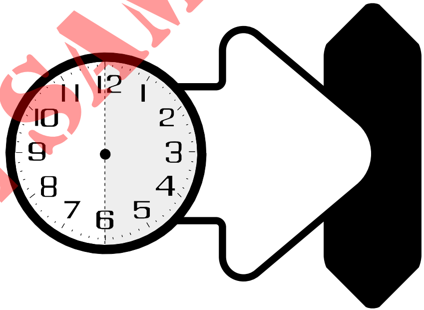
- Head and face
- Hands and feet (including soles of the feet)
- Open wounds
- Areas visibly contaminated

Also pay attention to skin folds and other areas where contamination could be shielded from detection. (Note: Blood, water, and other fluids can also shield alpha particles from detection.)

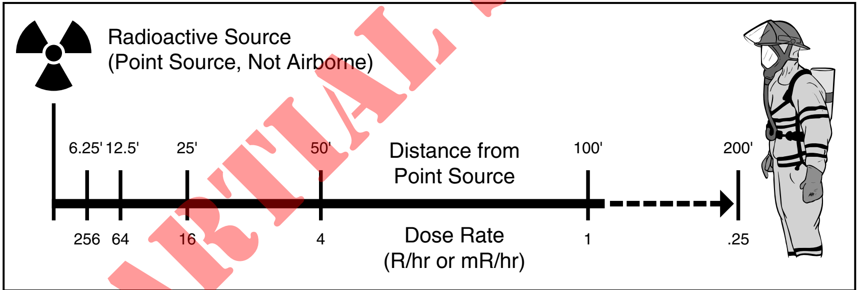
Chapter 6

Time, Distance, and Shielding

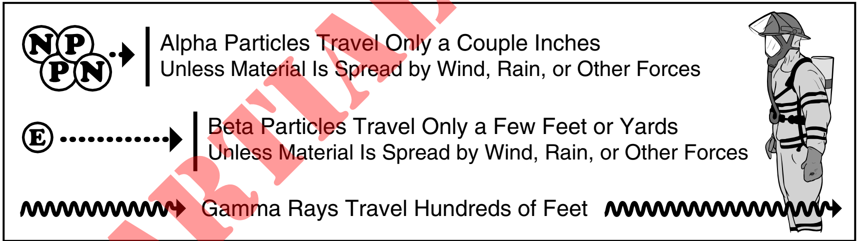
Effective use of time, distance, and shielding can help you keep radiation exposures *as low as reasonably achievable*—the *ALARA Principle.*



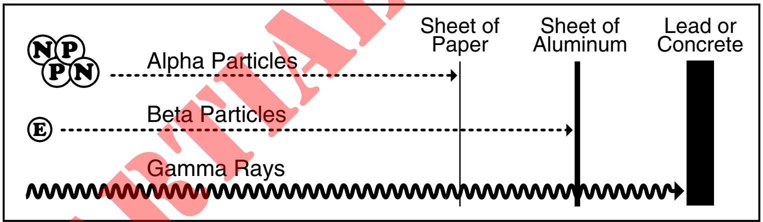
Distance is generally a more important factor than time is in controlling exposure. Whereas cutting exposure time in half cuts the dose in half, **doubling your distance from the radioactive source reduces exposure by 75%**. This is known as the **Inverse Square Law**. Note: This applies to a point source, not an airborne source.



Distance is also effective in reducing the *type* of exposure. Alpha particles travel only a couple inches in air. Beta particles travel several feet to several yards. Unless you have the contaminant on you or the material is being spread by wind, rain, or other forces, once you back out of the area, you are no longer at risk from alpha and beta particles. You need only worry about gamma radiation.



Appropriate shielding will help reduce your exposure. The relatively large alpha particles are stopped by shielding as thin as a sheet of paper. It takes heavier shielding, such as a thick piece of aluminum or an inch of wood, to stop beta radiation. Gamma radiation is so penetrating that far denser shielding, such as several inches of lead or concrete, is required.

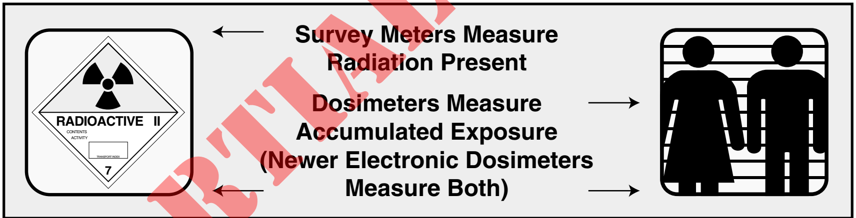


Chapter 7

Introduction to Radiation Monitoring

We cannot detect radiation through our senses. It can be sensed or measured only by special monitoring equipment. This chapter provides general information. For specific instructions on how to use your radiation detectors, refer to user manuals that came with them.

Most radiation meters used by emergency responders fall into one of two categories. **Survey meters measure radiation present** (dose rate) when the measurement is taken. **Personal dosimeters measure accumulated exposure** (dose) received by personnel working around radiation. (Newer electronic dosimeters can also measure dose rate—the amount of radiation present.)



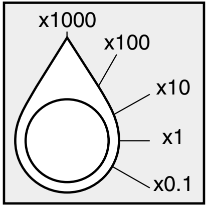
An electronic dosimeter capable of measuring dose rate (R/hr) has added value for emergency responders. When worn as part of the daily uniform, it **can alert the user to higher-than-normal radiation levels at *any* incident**, whether one suspects radiation or not. It works continuously and doesn't require the user to "operate" a meter the way one has to deploy a survey meter.

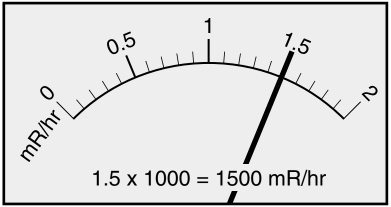
The programmable alarms can be set to any level deemed appropriate. For instance, one could set the dosimeter to alarm at 2 mR/hr, the point at which we'd normally establish an initial perimeter. (See pages 153 through 155 for information on background radiation.)

Understand the units of measure, and read the meter correctly. One of the most common mistakes people make is misinterpreting the reading. If you fail to read your meter correctly, you might either turn a minor problem into a major incident or inadvertently overexpose yourself and other responders. Remember: One roentgen (R/hr) equals 1000 milliroentgens (mR/hr) or 1,000,000 microroentgens (μR/hr).

1 R/hr = 1,000 mR/hr = 1,000,000 μR/hr

Know what scale you are reading. If your meter is set to the x1 (times 1) scale, the exposure rate is what you see on the meter. However, if the selector switch is set to x0.1, x10, x100, or x1000, the meter readings must be multiplied by 0.1, 10, 100, or 1000 respectively. For example, if your meter is reading 1.5 mR/hr, but the selector switch is set to x1000, the true exposure rate is 1500 mR/hr (or 1.5 R/hr). Relay readings to responders up-range, who are generally in a better position to record and interpret results.

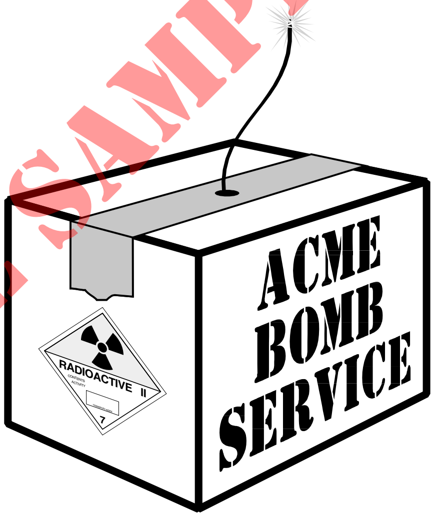




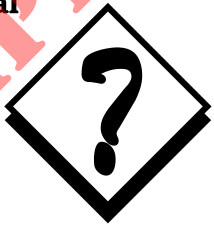
Chapter 8

Radiation and Terrorism

This chapter provides a brief overview of ways in which radioactive materials might be used for a terrorist event.



This chapter briefly looks at **several potential scenarios**:

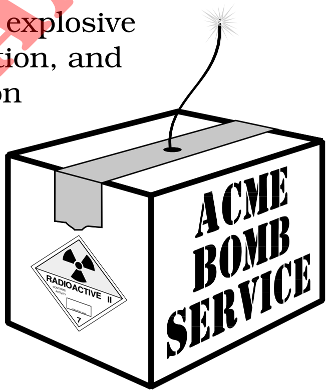


- A hoax or threat, with no actual event
- Planting a radioactive source near intended targets
- Dissemination with a spray device
- Contamination of food and water supplies
- Bombing of a nuclear facility or transportation vehicle
- Use of an improvised nuclear device (IND)
- Use of a radiological dispersal device (RDD)—a “dirty bomb”

The last one, use of a dirty bomb, is the most likely scenario, but the others are worth reviewing.

Use of a **radiological dispersal device (RDD)—a "dirty bomb"**—is the most likely scenario. A conventional explosive device, easy to make or purchase, could be used to disseminate common radioactive materials.

The greatest risk of injury is from the explosive itself (from blast pressure, fragmentation, and heat). Some radioactive contamination is likely near the blast site, but it's unlikely to be at lethal levels. Nonetheless, responders will have their hands full monitoring for contamination, decontaminating victims, and dealing with the inevitable fear and panic.



An RDD, or dirty bomb, is far less powerful than a nuclear weapon or nuclear bomb. Dispersion of radioactive materials would be limited to a few blocks or a few miles, depending on the size of the bomb, the radioisotope involved, and local conditions, such as weather and topography. And it will most likely involve low-level radioactive sources versus those that emit life-endangering levels of radioactivity. Health effects will depend on the type of radiation, the dose received, and route of exposure.

RDD and IND incidents require precautions not routinely practiced at ordinary explosives incidents. Precautions include, but are not limited to:

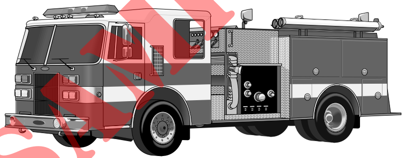
- Stay away from any obvious plume or dust cloud.
- Cover your mouth and nose to avoid inhaling or ingesting radioactive materials.
- Wear personal dosimeters, and use radiation detectors to monitor the area and people for contamination.
- Direct people to take shelter indoors until you've determined it's safe to go outside or relocate.
- If people have been contaminated, remove outer clothing and decon those individuals as soon as possible.
- Avoid consuming potentially contaminated food or water.

Chapter 10

Radiation Incident Management

This final chapter provides a brief summary of how to manage a hazmat or WMD incident (radiation or otherwise), based on the competencies outlined in NFPA 470—the standard for hazmat response (published by the National Fire Protection Association).

Make a safe approach.



- Approach from upwind, uphill, and upstream.
- Do not drive through spills or clouds.
- Maintain a safe distance.
- Park vehicles headed away from the scene for a quick escape.
- Avoid blocking other emergency vehicles.
- Be alert for signs of criminal or terrorist activity, including the possibility of secondary events or devices.

Provide a report on conditions as soon as possible. Speak clearly and distinctly, and include the following information:

- Notification of arrival on scene
- Updated address and location if appropriate
- Environment threatened
- Conditions upon arrival
- Whether criminal or terrorist activities are suspected
- Your proposed course of action
- Instructions to other responding units (e.g., safety concerns, staging areas, and assignments upon arrival)
- An estimate of resources required
- Any other pertinent information

Assume command using the incident command system (ICS). Effective use of the incident command system goes a long way to reducing chaos and making the incident run more smoothly.

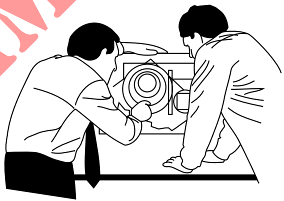
- Formally assume command.
- Establish a command post at a safe distance upwind, uphill, and upstream.
- Make sure the command post is clearly marked and that access is limited to avoid confusion.
- Manage the event until relieved by a higher authority.
- If multiple agencies respond, consider establishing a unified command post.

Establish an initial isolation zone (perimeter). This step is often referred to as *isolate and deny entry*. The initial perimeter should be set up where radiation levels are at or below 2 mR/hr.

If you can't determine actual radiation levels, use the current edition of the *Emergency Response Guidebook* to establish distances. Guides 161 through 165 in the ERG recommend the following minimum initial isolation/evacuation distances:

- 75 feet (25 meters) - isolation of spill or leak
- 330 feet (100 meters) - downwind evacuation for large spill
- 1000 feet (300 meters) - evacuation for large fire

Plan your initial response within the capabilities and competencies of available personnel, PPE, and control equipment. **Document your plan**.



- Establish roles and responsibilities.
- Determine what PPE is needed.
- Determine if there is a rescue involved and what resources are required to safely accomplish it.
- Set up decon and treatment areas as needed.
- Identify potential problems or risks.
- Incorporate a contingency plan for emergencies.
- Include a personnel accountability system.
- Identify procedures to preserve evidence.
- Establish a communications plan.

Conduct a safety briefing. Make sure all personnel understand the objective and their responsibilities. At minimum, the briefing should cover:

- Preliminary evaluation of the incident
- All identified risks (chemical, physical, and others)
- Site description, including site security and control
- Task(s) to be performed and time limits for doing so
- Appropriate PPE
- Monitoring requirements
- Emergency procedures (evacuation, decon, medical, etc.)
- Safe distances and areas of refuge
- Guidelines for preserving evidence
- Any other pertinent information

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Index (continued)