

The First Responder's Pocket Guide to Radiation Incidents

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SAMPLE

**Jill Meryl Levy
Firebelle Productions**



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The First Responder's Pocket Guide to Radiation Incidents

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The First Responder's Pocket Guide to Radiation Incidents

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Important Message to My Readers

This book contains a general overview of radioactive materials and guidelines for dealing with radiation incidents. It is not intended to take the place of formal training, more thorough references, or department SOPs.

Be smart and be safe. Use this book to brush up on the basics, but supplement it with other resources for a more comprehensive understanding of the topic. Know who your subject matter experts are, and call them promptly when you need assistance with an incident.



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SAMPLE

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.



Radiation is a form of energy. Radiation from both natural and manmade sources is around us daily. Examples include:

- The sun and outer space
- Our planet (rocks, soil, and vegetation)
- Heat (infrared), visible light, and ultraviolet light
- Radio and television waves
- Microwaves
- Medical and dental x-rays
- Some consumer products (e.g., smoke detectors, cigarettes, some foods)

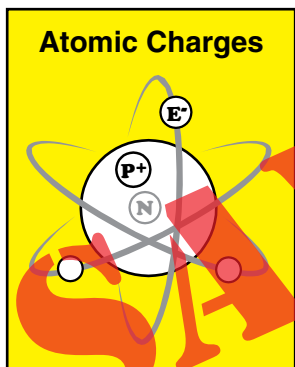


We're generally not concerned with **nonionizing radiation**, such as produced by microwaves, radio frequencies, heat, and light. That doesn't mean one can't be harmed by getting too close to a heat source, for example. But that's beyond the scope of this book.



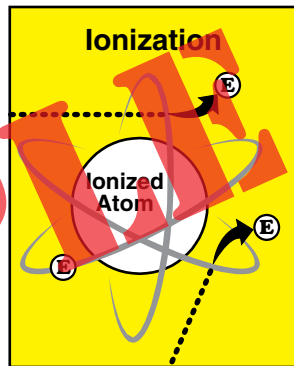
The electromagnetic waves produced by nonionizing radiation emit less energy than the electromagnetic waves produced by gamma rays and x-rays (two forms of ionizing radiation). The energy from nonionizing radiation can move atoms, creating heat, light, sound, etc. But the energy isn't sufficient to change atoms structurally, as happens with ionizing radiation.

Ionizing radiation produces enough energy to change the structure of atoms struck by that energy.



Each atom has a *nucleus* (center) filled with *protons* and *neutrons*. *Electrons* orbit the nucleus much the way planets orbit the sun. These electrons are said to reside in *shells* (sometimes called *orbits* or *rings*). Protons and electrons are electrically charged, protons positively (+1) and electrons negatively (-1). Neutrons have no electrical charge; they are neutral.

Atoms must have an equal number of protons and electrons to ensure a balance between positive and negative charges—to ensure the atom is electrically neutral. However, when struck by energy from ionizing radiation, the target atom will lose electrons and no longer be neutral. It is now **ionized**, and this effect is called **ionization**. Because ionization is a damaging process, we need to take precautions when encountering radioactive materials with the potential for greater exposure than the background radiation we're exposed to daily from natural and manmade sources.



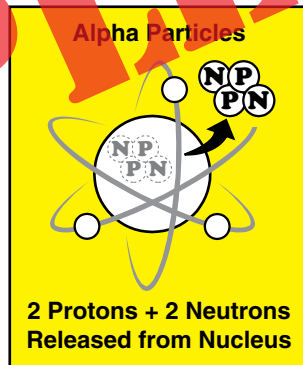
There are five types of ionizing (damaging) radiation:

- Alpha particles
- Beta particles
- Gamma rays
- X-rays
- Neutron particles

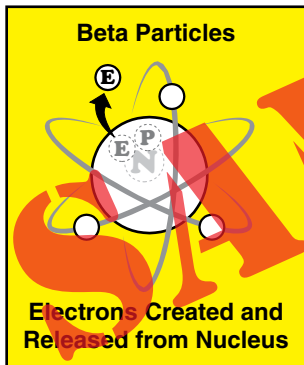
We'll define all five types, but this book focuses primarily on the first three—the three that responders are most likely to encounter at a radiation incident.



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.

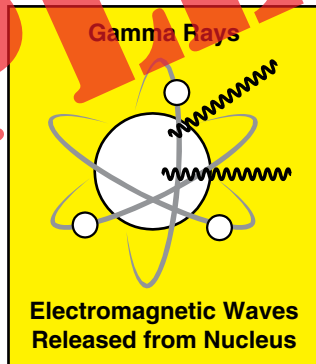


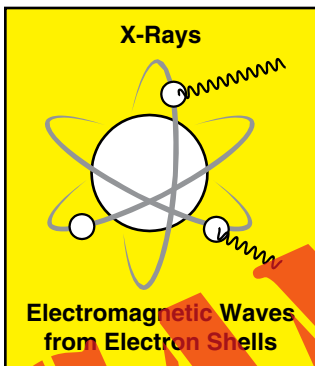
An excess neutron in the nucleus can transform into a proton and electron. The electron is then ejected as a **beta particle**. These relatively small particles can travel several feet to several yards in air. They vary in energy level. Those with the highest energy level can penetrate about a half-inch 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.



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.

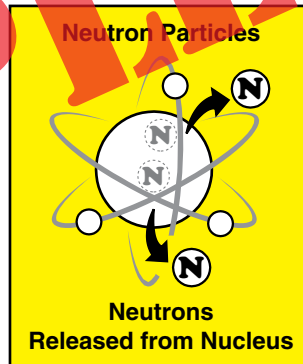
Although gamma emitters (radioisotopes that emit gamma radiation) can be inhaled, ingested, or absorbed through open wounds, most exposures to gamma rays are from an external source. Dense shielding, such as lead or concrete, is required to stop gamma radiation. Gamma emitters often emit alpha or beta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





X-rays originate in the electron shells. X-rays are similar to gamma rays, but they're less energetic and less penetrating. Most x-rays are produced by x-ray machines, such as those used in medical and dental facilities. Once the power is turned off, the machine is de-energized and no longer emits radiation.

Neutron particles (neutrons released from the nucleus of an atom) are larger than beta particles, but smaller than alpha particles. Neutron radiation has strong penetrating power and often causes more damage to body tissues than do other forms of ionizing radiation. However, neutron radiation is rare; it's primarily associated with nuclear power plants and nuclear bombs. Emission can occur as a result of fission (the splitting of an atom in a nuclear reactor or nuclear weapon) or as a result of bombarding a substance with alpha particles that collide with the nucleus and displace existing neutrons.



Most radioactive materials give off two or three types of radiation. The chart below shows a few examples.

Radionuclide	Alpha	Beta	Gamma	Radionuclide	Alpha	Beta	Gamma
Americium-241	✓		✓	Plutonium	✓	✓	✓
Cesium-137		✓	✓	Radium	✓	✓	✓
Cobalt-60		✓	✓	Technetium-99m		✓	✓
Iodine-129		✓	✓	Thorium	✓		✓
Iodine-131		✓	✓	Uranium	✓		✓

Radioactive materials may have other hazards too. For example, they may be flammable, toxic, or corrosive in addition to being radioactive. These hazards must be considered when planning a response.

Other terms categorize radioactive materials based on form, use, or activity. The following pages provide only generic descriptions. Various state and federal regulations contain more specific details on which materials fall into each category.

- Special form materials (sealed sources)
- Low specific activity (LSA) materials and surface contaminated objects (SCO)
- Low-level waste
- Fuel rods
- High-level waste (spent fuel and associated wastes)
- Transuranic waste (TRU)
- Uranium mill tailings
- Fissile materials (special nuclear materials)



Special form materials typically contain radioisotopes that emit a high level of radioactivity. However, they are encapsulated in durable containers of such high integrity that a breach is unlikely. The only way to open the containers is to destroy them.



The containers used for special form materials usually look like nondescript stainless steel cylinders. The key to recognizing them is to look for the radioactive trefoil symbol and related markings on the exterior. (As you'll see, the outer packaging for many radioactive materials looks no different from other fiberboard, wooden, or metal containers. So responders must rely on stencils, labels, placards, and shipping papers rather than container shape.)

Low specific activity (LSA) materials

are those with a low level of specific activity (rate of decay) or those in which the radioactivity is uniformly distributed throughout a large amount of a nonradioactive material (e.g., earth, concrete, rubble, or other debris). Closely related are **surface contaminated objects (SCO)**—nonradioactive materials externally contaminated with a low-level radioactive substance. Both present minimal risk to responders. Specific descriptions for LSA-I, LSA-II, LSA-III, SCO-I, and SCO-II materials are found in 10 CFR 71.4.



Nuclear power plants, hospitals, universities, and other industries that use radioactive materials generate contaminated waste. **Low-level waste**, such as lab supplies, discarded protective equipment, cleaning rags, and filters, emit only small amounts of radiation. These items are not a cause for alarm, but they must be handled according to regulations. (Low-level waste is one form of an LSA material.)



Fuel rods—long tubes filled with ceramic pellets created from uranium, a radioactive element abundant in the earth's crust—are a key component of the nuclear power cycle. In a process called *fission*, uranium atoms split and release neutrons from the nucleus. The heat produced through this process heats the water circulating around the fuel rods. The heat creates steam, which turns a turbine connected to a generator, creating the energy to produce electricity. Fuel rods that have not yet been in a nuclear reactor emit very little radioactivity.



Spent fuel—fuel rods removed from the reactor—is highly radioactive because it contains fission by-products created in the nuclear reactor. Spent fuel continues to lose energy through radioactive decay, but it remains radioactive for thousands of years.



Spent fuel and waste materials from operations where spent fuel is reprocessed both constitute **high-level radioactive waste**. High-level waste is transported in heavily shielded casks. Spent fuel rods are also stored at most commercial nuclear reactors.

Transuranic waste (TRU) is material (including protective clothing, tools, glassware and equipment) contaminated with radioisotopes heavier than uranium, meaning beyond uranium on the periodic table of elements. (See page 34.) Most transuranic waste is no more radioactive than low-level waste, but it remains radioactive far longer.

“Contact handled” transuranic waste can be safely handled by workers without special protective clothing and may be packaged in drums or metal boxes. A small percentage of transuranic waste, categorized as “remote handled,” emits enough radiation that it must be packaged in shielded casks instead.



Uranium mill tailings are radioactive rock and soil by-products that result from mining and milling uranium for use in weapons and nuclear reactors. When the naturally occurring radium in these mill tailings decays, it emits radon gas. Radon is harmless if dispersed into the atmosphere, but it can be harmful if a person breathes it in high concentrations over a long period. It's the second leading cause of lung cancer in the United States today.

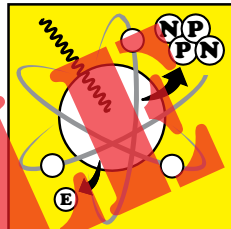


Note: See the EPA's web site (<http://www.epa.gov>) for information on how radon from the natural decay of uranium in soil and rock can enter and build up inside homes and other buildings.

Fissile materials (uranium-233, uranium-235, plutonium-239, and plutonium-241), also known as *special nuclear materials*, are of particular concern because they can be used to create an atomic bomb. (Per 49 CFR 173.403, the term *fissile material* excludes some forms of these isotopes, but the details are beyond the scope of this book.) Tight restrictions govern the production and use of fissile materials.

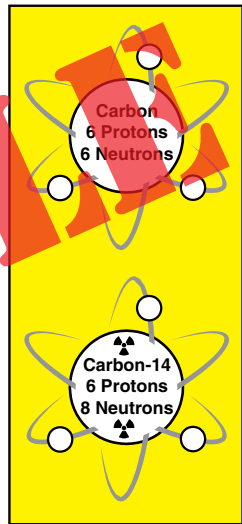


Radioactive elements are unstable atoms. When atoms give off radioactivity, they are throwing off excess energy and/or particles to become stable, as illustrated earlier in the chapter. This process is called **radioactive decay** or **disintegration**.



While it is beyond the scope of this book to explain how this complex process works and the variations that exist among the different radioactive materials, the bottom line is that atoms cast off bits of themselves to become stable.

The names of radioactive elements may be modified by a number, for example, carbon-14 (^{14}C) or cobalt-60 (^{60}Co). The number indicates that the element contains more neutrons than normal. The predominant form of carbon, for example, contains six protons and six neutrons. Carbon-14 has six protons and *eight* neutrons. Multiple forms of the same element are called **isotopes**. Isotopes have similar chemical properties, but some isotopes are stable and others are radioactive. You can find these chemical properties listed in various reference books.



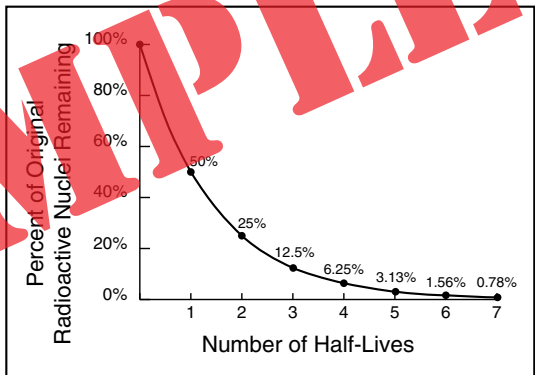
Many elements with atomic numbers 84 (polonium) and above may give off radioactivity in their natural forms.

When looking at a periodic table, you should consider any element from polonium on (atomic number 84 and above) potentially radioactive in its natural form.

The Periodic Table of Elements & Elements That Should Be Considered Naturally Radioactive

Alkali Metals																		Alkaline Earth Metals																		Transition Metals																		Main Group Elements																		Noble Gases																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
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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.



Half-life *doesn't* mean that atoms disappear. Rather, **when a radioactive material decays, it essentially “morphs” into something else** through a series of intermediate steps.

Every atom of the same element has exactly the same number of protons. So when protons are lost or gained in the decay process, atoms change to other elements on their way to becoming stable. For example, uranium-238 (half-life of 4.5 billion years) goes through roughly a dozen transformations before turning into lead-206, a stable element. The original radionuclide is known as the “parent.” Other elements in the decay chain are called “daughters.”



Daughter products may have different hazards and give off different types of radiation than the parent does. It's not a reason to be afraid of radioactive materials, but it is a compelling reason to seek assistance from subject matter experts.

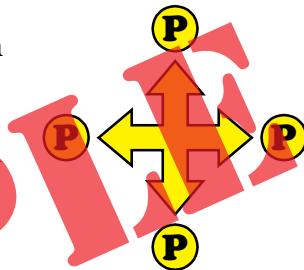


This also becomes significant when monitoring. For example, if your survey meter indicates the presence of beta particles from a material not known to emit beta radiation, the detector could be reacting to emissions from a daughter product. It's not necessarily operator error, faulty equipment, or misinformation on a label or shipping paper.

The term *fission* was introduced earlier in the chapter, but let's now take a closer look at it. **Fission** is a process in which a large nucleus splits into two smaller nuclei. It's a process that has been taking place in the universe for billions of years—and one that scientists have been able to re-create both for peaceful purposes (to produce energy in nuclear power plants) and not-so-peaceful ones (to build atomic bombs).

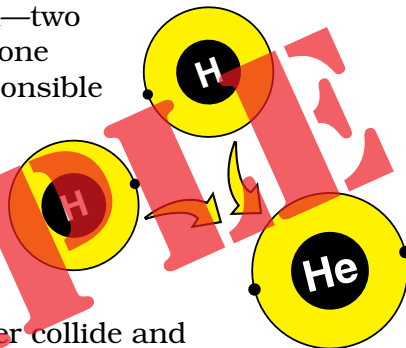


Fission occurs because of competing atomic forces. The nucleus of an atom is held together by a strong attractive force between protons and neutrons. However, among the positively charged protons is a repulsive electrostatic force (like repels like) that would drive the protons apart if it weren't for the neutrons—a sort of “nuclear glue.”



In a **fission reaction**, the strong electrostatic repulsion between protons overcomes the attractive force that normally keeps the nucleus together, and the nucleus splits into two smaller nuclei, where there is less internal electrostatic repulsion because there are fewer protons.

Fusion is the opposite of fission—two smaller nuclei combine to form one larger one. It's the process responsible for the energy output of our sun and other stars in the universe. Stars initially consist of hydrogen (H) and helium (He). As hydrogen isotopes collide, they fuse to form helium. Helium nuclei later collide and form heavier elements, which subsequently do the same thing.



Fusion doesn't happen spontaneously on Earth because the electrostatic repulsion between nuclei is too great. However, scientists have been able to produce **fusion reactions** by squeezing nuclei so close to one another that the attractive force between protons and neutrons overcomes the normal electrostatic repulsion. This is the reaction behind thermonuclear weapons (hydrogen bombs).



This book stresses the dangers of radiation, but **radiation has many beneficial uses**. The following is a partial list:

- Generate energy (nuclear power plants)
- Diagnose and treat medical conditions
- Sterilize medical equipment
- Kill bacteria and preserve food
- Detect explosives
- Inspect welds for cracks
- Gauge the thickness of various materials
- Measure moisture content in soil, asphalt, etc.
- Analyze substances using gas chromatographs
- Determine age of materials via carbon dating
- Locate underground resources (for drilling and mining)



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.



We all receive a small amount of ionizing radiation

(average 360 mrem) every year, roughly 82% from natural sources and 18% from manmade sources. (Rem and mrem are defined on page 51.) The National Council on Radiation Protection and Measurement estimates the sources of radiation exposure to break down as shown below.

%	Source of Average Annual Dose of Ionizing Radiation
55%	Radon (from radioactive decay of uranium-238 in rock and soil)
11%	X-rays and other medical and dental procedures
11%	Internal (materials such as potassium and carbon in food and air)
8%	Terrestrial (other naturally occurring radioactive materials in the Earth's crust)
8%	Cosmic radiation
4%	Nuclear (emissions from power plants and fallout from nuclear weapons testing)
3%	Consumer products (e.g., cigarettes, smoke detectors, color televisions)
1%	Other

The U.S. EPA has published recommended dose limits for workers performing emergency services.

Doses to all workers during emergencies should, to the extent practicable, be limited to 5 rem. The chart below shows situations for which higher doses may be justified if the benefits outweigh the risks. Exceeding the 25-rem limit to save lives should be considered only on a voluntary basis and only with a full awareness of the risks involved, including the health effects at the anticipated doses.

Dose Limit	Activity	Condition
5 rem	all	
10 rem	protecting valuable property	lower dose not practicable
25 rem	life saving or	
> 25 rem	protecting large populations	
		voluntary basis, fully aware of risks

The EPA limits still leave a safety margin. Although there may be some mild effects with doses as low as 30 rems, most people won't develop "radiation sickness" at less than 70 to 100 rems. Nonetheless, **radiation exposures should be kept as low as reasonably achievable.** (This is known as the **ALARA Principle.**) Further, the EPA recommends that doses to workers performing emergency services be treated as a once-in-a-lifetime exposure.

Of course, these limits have no value unless you understand what they mean. So let's define them.



English units of radiation measure are used most often in the United States:

- Roentgen (R)
- Rad (radiation absorbed dose)
- Rem (roentgen equivalent man)
- Curie (Ci)

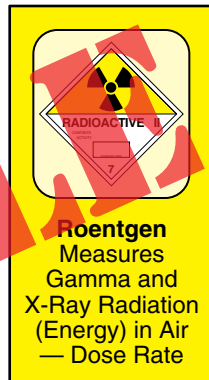


The **International System (SI) of Units** is used on labels and shipping papers and in most places internationally:

- Gray (Gy)
- Sievert (Sv)
- Becquerel (Bq)



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 μ R/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.)



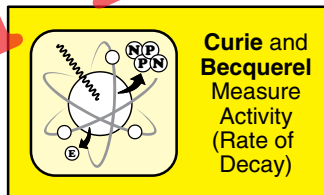
Rad (radiation absorbed dose) describes radiation energy absorbed by exposed matter (living or not). The international equivalent of rad is **gray (Gy)**. However, 1 gray equals 100 rads.

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.

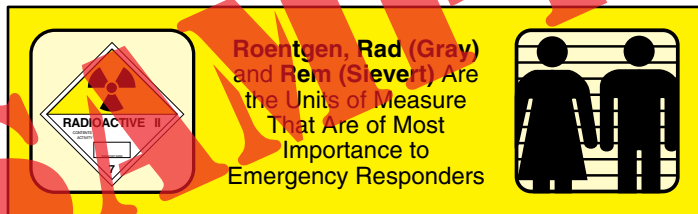


Curies (Ci) measure activity (rate of decay). One curie (Ci) is the quantity of radioactive isotope that produces 37 billion disintegrations per second (dps). For regulatory purposes, the DOT defines a radioactive material as any material having a specific activity greater than 0.002 microcuries (0.002 μCi) per gram. (A microcurie is one millionth of a curie.)

The international **becquerel (Bq)** is similar. However, 1 becquerel equals 1 disintegration per second. Thus 1 curie equals 37 billion becquerels (37 GBq).



When comparing radioactive materials, the higher the number of curies or becquerels, the more hazardous the isotope. However, curies and becquerels don't tell the first responder about human exposure. **So roentgen, rad (gray), and rem (sievert) are the units of most importance to emergency responders.**



The following equation shows the **approximate relation between the five units of measure** that are of most importance to emergency responders.


$$100 \text{ roentgens} = 100 \text{ rads (1 gray)} = 100 \text{ rems (1 sievert)}$$

The equation is not precisely accurate (see next page), but it is close enough to be used for practical purposes. For example, if your meter reads 100 R/hr, you can expect to be exposed to 100 rems (1 Sv) if you remain in that atmosphere for 60 minutes.

In reality, the **effective biological damage** (measured in rems or sieverts) is determined by multiplying the number of rads or grays by a *quality factor* that varies with the type of radiation. This is because some types of radiation are more harmful than others.

$$\begin{array}{r} \text{Rads/Grays} \\ \times \text{Quality Factor} \\ \hline \text{Effective Biological Damage} \end{array}$$

The equation on the previous page is close enough for first responders. However, if you see exposure levels cited in terms of rads/grays instead of rems/sieverts, recognize that it's raw data subject matter experts may fine-tune to reflect biological damage based on type of radiation and how easily different body organs absorb and are damaged by radiation.

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

You can also **calculate incident stay time with any of the equations below**. To understand where the “constant” comes from, multiply 60 (as in minutes) by the appropriate EPA exposure limit (page 47). For example, for lifesaving operations (25-rem limit), you can spend 60 minutes in a 25-R/hr atmosphere ($60 \times 25 = 1500$). Exposure rate and time may vary, but the number 1500 is a constant. For protecting valuable property (10-rem limit), the constant is 600 ($60 \times 10 = 600$). For anything else (5-rem limit), the constant is 300 ($60 \times 5 = 300$).

EPA Limit	Constant	Meter Reading	Stay Time
25 rems ...	$1500 \div$	___ R/hr =	___ Minutes
10 rems ...	$600 \div$	___ R/hr =	___ Minutes
5 rems ...	$300 \div$	___ R/hr =	___ Minutes

The incident stay time table (page 57) and the equation on the previous page can help you plan the work mission duration. However, to monitor actual exposure, **you should wear a personal dosimeter anytime you know or suspect radiation is present.**

This includes incidents where there has been an explosion. Electronic dosimeters equipped with alarms are best. See Chapter 7 for information on radiation monitoring.



The prefixes *milli* and *micro* (e.g., millirem and microroentgen) were introduced earlier. Some of the other **prefixes** you might see are shown below.

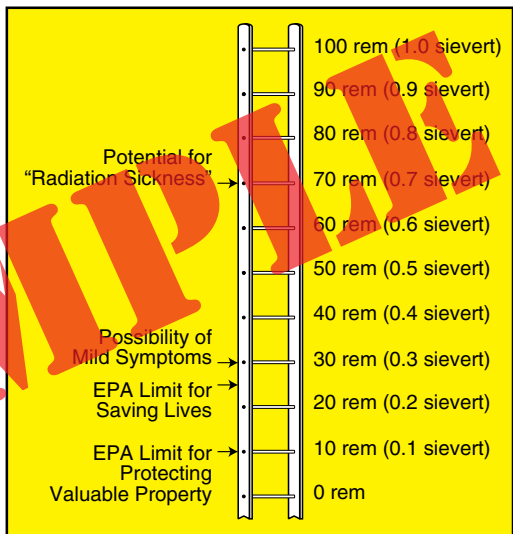
Unit	Symbol	Power	Equivalent	Numeric Representation
Tera	T	10^{12}	trillion	1,000,000,000,000
Giga	G	10^9	billion	1,000,000,000
Mega	M	10^6	million	1,000,000
kilo	k	10^3	thousand	1,000
—	—	1	one	1
milli	m	10^{-3}	thousandth	1/1,000
micro	μ	10^{-6}	millionth	1/1,000,000
nano	n	10^{-9}	billionth	1/1,000,000,000
pico	p	10^{-12}	trillionth	1/1,000,000,000,000

Familiar monetary units can help you picture the relation between these prefixes. This perspective is helpful when sizing up an incident. How do meter readings compare to normal background levels? (See pages 153 through 155.) How do they compare to the EPA exposure limits on page 47 for protecting valuable property (10 rems) or saving lives (25 rems)? Figuratively speaking, are you dealing with pennies, dollars, or large bills? (We could replace rem with anything else, and the relation would be the same.)

Radiation in Perspective	
Exposure	\$ Comparison
1 μ rem	0.1¢
5 μ rem	0.5¢
10 μ rem	1¢
25 μ rem	2.5¢
1 mrem	\$1
5 mrem	\$5
10 mrem	\$10
25 mrem	\$25
1 rem	\$1,000
5 rem	\$5,000
10 rem	\$10,000
25 rem	\$25,000
Courtesy: George D. Moshø, Health Physics Society	

Some people use **hazard ladders for a visual representation of exposure values.**

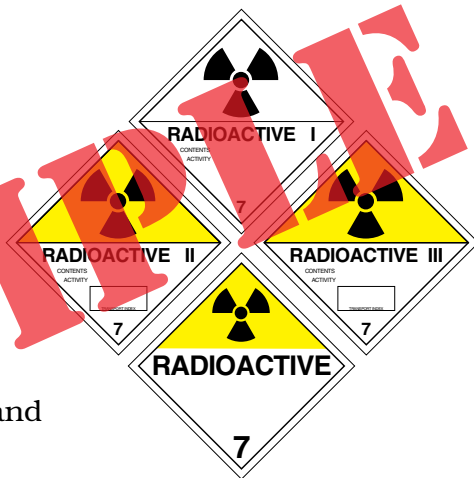
This one plots the EPA recommended exposure limits (page 47) relative to where one might expect the early health effects described in Chapter 4. However, you can change the scale to plot almost anything.



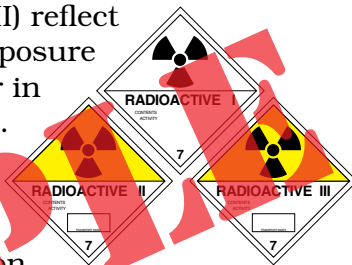
Chapter 3

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.



Three **labels** (Radioactive I, II, and III) reflect the maximum potential radiation exposure that a person could receive per hour in close proximity to an intact package. Materials labeled Radioactive I are the least hazardous, while those labeled Radioactive III are the most hazardous. Labels must be placed on two opposite sides of the package.



Placards are required on vehicles transporting Radioactive III materials (those that emit the highest level of radiation) and vehicles used for exclusive use shipments (explained on page 71).

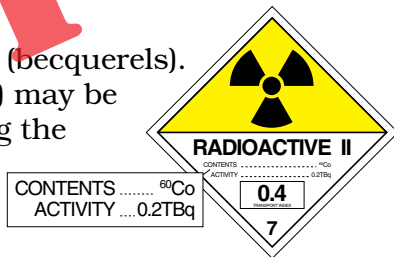
The designation of Radioactive I, II, or III is based on radiation level (dose rate) as measured both at the surface of the package and at 1 meter (3 feet) away. Shown below are the maximum limits associated with each label—the maximum exposure rate one should detect *above normal background levels*.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

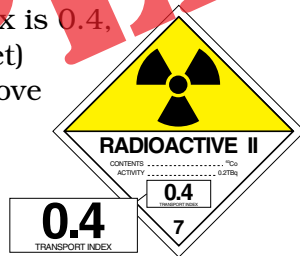
The **contents** are normally identified by name, but they may be identified by authorized symbols instead (e.g., ^{60}Co versus Cobalt-60). Low-specific activity (LSA-I) materials may be identified with the term *LSA-I* instead of the actual radionuclide.

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.



A **placard on a square background** means the vehicle contains a **highway route controlled quantity (HRCQ)** ... a high-level radioactive material, such as spent fuel, shipped along designated routes.



These designated routes (known as *preferred routes*) consist of interstate highways and bypass roads around cities. They may include alternative routes selected by a state or tribal authority in cooperation with affected state and local agencies. Preferred routes are chosen based on an evaluation of risk factors such as accident rate, transit time, population density, activities/occupancies along the route, time of day, and day of the week.

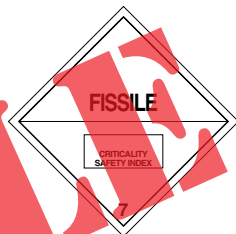
A **subsidiary corrosive placard** is required when transporting 1001 pounds or more gross weight of fissile or low specific activity uranium hexafluoride.



An **orange panel with the material's UN identification number** may be affixed next to the placard, but the UN number cannot be used on the placard itself.

2978

Fissile labels may be affixed to packages containing fissile materials, depending on how they fall into the requirements or exceptions under Title 49. The *criticality safety index (CSI)* on the label is not a radiation measurement; rather, it's a number used to limit accumulation of containers containing fissile materials.



An **empty label** means that the package previously containing a hazardous material has been emptied as far as practical. It does not mean that the container has been cleaned and purged.

When a package exceeds the Radioactive III limits identified on page 65, it must be transported by **exclusive use shipment**. The following are some of the requirements:

- The package must be shipped in an *exclusive use vehicle* (one used by a single consignor).
- All loading and unloading is done in accordance with the directions of the consignor or consignee.
- The consignor must provide the carrier with written instructions for maintaining the shipment.
- Any loading and unloading is done by personnel having radiological training and resources appropriate for safe handling of the shipment.



Radiation limits are structured differently for exclusive use shipments. Again, these represent maximum readings *above normal background levels*.

Reading Location	Maximum Reading
In any normally occupied space (e.g., cab of vehicle)	2 mR/hr
Outer surface of vehicle	200 mR/hr
2 meters (6.6 feet) from outer surface of vehicle	10 mR/hr
External surface of package	200 mR/hr *
External surface of package	1000 mR/Hr (1 R/hr) **
* Lower limit applies if the following conditions are not met. ** Higher limit applies if (1) shipment is made in a closed transport vehicle, (2) package is secured to prevent movement during shipment, and (3) there are no loading or unloading operations between the beginning and end of the transportation.	

Radioactive materials and wastes are placed in one of **six types of packages** based on their level of radioactivity. Each is explained in more detail on the following pages.

Package	Materials Transported
Excepted	Extremely low levels of radioactivity
Industrial	Low levels of radioactivity
Strong-Tight	Low levels of radioactivity
Type A	Higher levels of radioactivity, not life-threatening
Type B	Highest level of radioactivity, potentially life-threatening
Type C	Highest level of radioactivity, potentially life-threatening

The higher the level of radioactivity, the stronger the package must be. Specific tests are used to determine if a package design can withstand various transport and accident conditions.

Excepted packages are used for materials with extremely low levels of radioactivity. The packages range from fiberboard boxes to sturdy wooden or steel crates. Smoke detectors (with Americium-241) are a common example of items found in excepted packages. Excepted packages are not put to any strength tests, but they must be designed to provide ease of handling and reasonable strength during transportation.



Industrial packages are used to transport materials with low levels of radioactivity (such as uranium or thorium ores and concentrates) that present a limited hazard to the public and the environment. The three categories (IP-1, IP-2, and IP-3) are based on package strength.



Package	Design / Test Requirements
IP-1	Same as excepted packages
IP-2	Must pass Type A free-fall and compression tests
IP-3	Must pass all Type A tests for solid contents

Strong-tight packages are used for certain low-level radioactive materials, such as natural uranium and rubble from decommissioned nuclear reactors. These packages are restricted to materials with a low hazard and historical safety record and are authorized only for domestic shipments in vehicles hired exclusively for those shipments. Consequently, they are not required to meet all the general design requirements for radioactive materials packaging. The packages may be constructed of steel, wood, or fiberboard. (Some reference sources no longer list strong-tight containers.)



Type A packages are used to transport relatively small quantities of radioactive materials (such as radiopharmaceuticals and low-level waste) with higher concentrations of radioactivity than are allowed in the three previous packages. Type A packages typically have three layers to shield and

protect their contents. As was true for the other package types pictured so far, the outer container may be made from a variety of materials ranging from fiberboard to metal. Therefore, labels, stencils, and shipping papers will provide more reliable recognition clues.



Type A packages are designed to protect and retain their contents under normal transport conditions and in minor accidents. Although they may be breached under severe accident conditions, their contents are not life-endangering.

To earn a **Type A rating**, the package design must successfully pass four **tests**, the details of which are spelled out in 49 CFR 173.465.

- Water spray (simulating heavy rain)
- Free-fall drop
- Stacking (compression)
- Penetration (from a bar dropped onto the package)



Type B packages, used to transport materials with the highest level of radioactivity, are designed to protect and retain their contents in both normal and severe accident conditions. They are more robust than Type A packages and range from small drums to heavily shielded steel casks that can weigh more than 98 tons (89,000 kg). Examples of materials transported in Type B packages include spent fuel, high-level radioactive waste, and high concentrations of some isotopes.



The **tests for Type B package designs** are more severe than those for Type A designs and are spelled out in 10 CFR 71.73. They include:

- Free-fall drop
- Crush
- Puncture (from the package being dropped on an upright steel bar)
- Thermal (actual or simulated flame impingement)
- Water immersion



Type C packages, as defined by the International Atomic Energy Agency (IAEA), are designed for air transportation of materials with high levels of radioactivity (including plutonium). They are not authorized for domestic use but are authorized for international shipments. Type C packages are designed to withstand severe air transport accidents without loss of containment or significant increase in external radiation levels. The performance requirements are more stringent than they are for Type B packages, simulating the stress a package might be subjected to if an aircraft crashes.



Type B and C packages are the only ones that contain potentially life-endangering amounts of radioactive materials. So **just by knowing the type of package** (usually identified on the container and on shipping papers), **you can make a quick estimate about the degree of risk** posed by the material and the likelihood of a breach based on severity of impact in an accident.

Package Type Contains Potentially Life-Endangering Amounts of Radiation?	
No	Yes
Excepted Industrial Strong-Tight Type A	Type B Type C

Radioactive materials are also “packaged” in a variety of instruments that responders might encounter in the field. Examples include:

- Radiography cameras used to examine welds in pipelines, boilers, and pressure vessels
- Moisture density gauges that measure density and moisture of asphalt
- Thickness gauges used for producing textiles and papers
- Level gauges used in tanks where heat, pressure, or corrosive materials make other gauges impractical

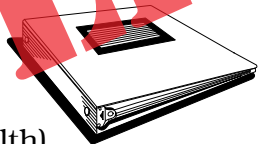


Never rely solely on labels, placards, and packaging. For transportation incidents, request **shipping papers** from the responsible party as soon as possible. Shipping papers provide more details about the hazardous material. They also identify the shipper and provide 24-hour emergency phone number(s).

Mode	Shipping Paper	Location
Highway	Bill of Lading	Cab (in easy reach of driver)
Rail	Waybill and Consist	Engine or caboose (with conductor)
Water (Ship)	Dangerous Cargo Manifest	Holder on or near bridge
Water (Barge)	Dangerous Cargo Manifest	Accessible spot, copy on tow vessel
Air	Airbill	Cockpit (with pilot)

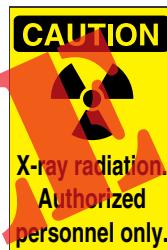
Obtain **material safety data sheets (MSDS)** whenever possible. MSDSs are required at fixed facilities, but they may be attached to shipping papers. MSDSs can also be faxed to the scene by manufacturers, CHEMTREC, or other resources. MSDSs contain the following information:

- Chemical and common name(s)
- Hazardous ingredients (for mixtures)
- Physical and chemical characteristics
- Hazards (fire, explosion, reactivity, health)
- Exposure limits
- Control measures
- Precautions for safe handling and use
- Emergency and first aid procedures
- Manufacturer name, address, emergency phone number



**Signage (postings)
at fixed facilities**

differs from that in transportation. You may still see the labels illustrated earlier on individual packages, but you will also find signs similar to those illustrated here.



The **wording on facility signage (postings) reflects the potential radiation exposure.** (Source: 10 CFR 20.1902.)

Facility Signage	Potential Radiation Exposure
Caution Radiation Area	>0.005 rem (0.05 mSv) in 1 hour at 30 centimeters (11.8 inches)
Caution or Danger High Radiation Area	>0.1 rem (1 mSv) in 1 hour at 30 centimeters (11.8 inches)
Grave Danger Very High Radiation Area	>500 rads* (5 grays*) in 1 hour at 1 meter (39.37 inches)
Caution or Danger Airborne Radioactivity Area	Airborne dusts, fumes, particulates, mists, vapors or gases
Caution or Danger Radioactive Materials	Licensed material greater than 10 times the licensing threshold for the radionuclide

* 10 CFR 20 switches to rads/grays when referring to very high doses received at high dose rates.

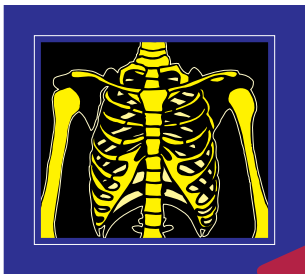
SAMPLE

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.

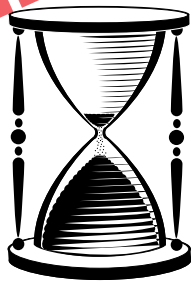
People can become internally contaminated

if radioactive materials enter the body through inhalation, ingestion, or contamination of an open wound. They can subsequently expose others nearby.

The body fluids (blood, sweat, and urine) of internally contaminated people may contain radioactive materials that can contaminate and/or expose others. Standard universal precautions (gloves, handwashing, etc.) will help protect emergency personnel from contact with these fluids.



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 LD₅₀/60 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.



- **Above 1000 rems** (10 Sv), the chances of survival drop significantly, even with aggressive treatment.
- Patients exposed to **5000 rems** (50 Sv) will die within 48 hours. There is no effective treatment for such acute exposures. Treatment is limited to making patients as comfortable as possible.



Note: Some experts use rads/grays instead of rems/sieverts when describing health effects. At the first responder level, there's very little difference. However, rads/grays is raw data, whereas rems/sieverts is "fine-tuned" to reflect effective biological damage. (This is explained on page 55.)

Aside from the radiation sickness described over previous pages, ionizing radiation can **disrupt normal cell growth and repair processes**, resulting in an increased risk of cancer—often considered the primary health effect. Or radiation can **cause changes in DNA**—mutations that affect a developing fetus (teratogenic effects) or that can be passed from parent to child (mutagenic effects).



Other health effects include damage to the blood-forming organs, sterility, or other damage to the reproductive system.

Partial body exposure results in radiation burns that develop slowly, although patients may also experience the early nausea and vomiting typical of whole body exposures.



- Roughly 2 to 3 weeks after partial body exposures of 300 to 1000 rems (3 to 10 Sv), effects may resemble a first-degree sunburn.
- Higher exposures—up to 2500 rems (25 Sv)—will produce blisters within 1 to 2 weeks.
- Partial body exposures exceeding 3000 rems (30 Sv) may cause slow-healing ulcers or gangrene.
- Extremely high exposures manifest with tingling, pain, redness, and swelling very soon after exposure.

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 (N-95 HEPA filter or equivalent).

Serious medical problems take precedence over radiation concerns, such as monitoring and decon, because radiation injuries are not immediately life-threatening, whereas other injuries can be.



Nonetheless, use common sense. If patients are grossly contaminated, you can reduce the risk of secondary contamination to yourself and other EMS providers by quickly removing the patients' outer clothing and doing emergency decon. However, remember that serious medical concerns always take precedence.

Remove contaminated clothing as soon as practical. Doing so can remove most of the contamination. (Note: It may be sufficient to remove just outer clothing. It's not necessary to compromise a patient's modesty if only the outer layer of clothing is contaminated.)



Avoid lifting clothing over the face, which increases the risk of inhalation exposures. Cut clothing off instead, if necessary, rolling the clothing away from the face to contain the contamination. Sometimes with radioactive dusts or powders, wetting the clothing during removal can help prevent the material from becoming airborne.

Isolate contaminated clothing, shoes, jewelry, and other personal items in double plastic bags labeled with each patient's name and clearly marked "Radioactive—Do Not Discard." For multiple patients, bag each person's clothing and possessions separately.

Warning: Treat contaminated clothing as a potential radioactive source until proven otherwise.



Cleanse the skin with lukewarm water or soap and water. Use low water pressure and a gentle spray. If contamination is minimal, cleansing with a mister, wet towel, or moist towelette may be preferable.

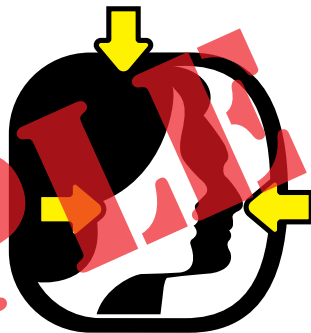
Decontaminate the head first, starting with eyes, mucous membranes, and open wounds, since they will more readily absorb hazardous materials than will intact skin. Avoid flushing the contaminant into eyes, nose, mouth, wounds, or uncontaminated areas of the body. Avoid irritating or otherwise compromising intact skin.



Pay particular attention to areas of the body where chemicals may become trapped (e.g., hair, nostrils, ears, nail beds, armpits, skin folds, and private areas).

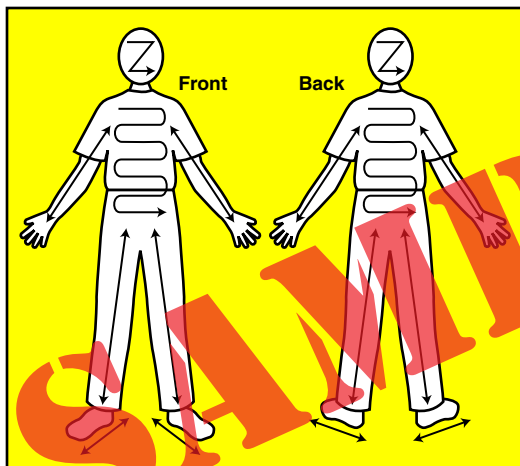
If inhalation is suspected, consider taking a nasal swab for later analysis.

Protect the patient's modesty as much as possible.



If the eyes have become contaminated, **flush the eyes with water or saline for at least 15 minutes.** Use low water pressure to avoid further injuring the eyes. Flush from the inside of the eyes toward the outside to avoid flushing material from one eye to another. If patients are wearing contact lenses, direct patients to remove contacts or carefully do it for them. Put contact lenses in a safe location. Have patients keep their eyes open while you are flushing, and don't let patients rub their eyes.



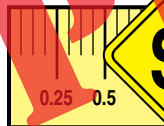


Use radiation detectors to ensure patients are fully decontaminated. Systematically survey from head to toe on all sides.

(Note: The following pages deal only with patient monitoring. General monitoring information is covered in Chapter 7.)

Hold the probe one half inch from the body. Alpha particles, in particular, can't be detected if you don't hold the probe close enough. Be careful, however, not to touch the probe to any contaminated surface. If you contaminate the probe itself, you will "detect" radiation every place you monitor until you decontaminate the probe.

Move the probe slowly (no more than two inches per second), or you may miss something.



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.)



Follow local protocols regarding the need for decon (or additional decon) based on contamination levels.

In general, a person is considered adequately decontaminated if meter readings don't exceed twice the background radiation levels. (See pages 153 through 155 for information on background radiation.) Some experts are comfortable citing three to five times the background levels instead, particularly in a mass casualty incident or situations where no further contamination reduction is achieved through additional decon. Seek advice from your state or local radiation officer.



Mass casualty incidents may require modifying the decon procedures.

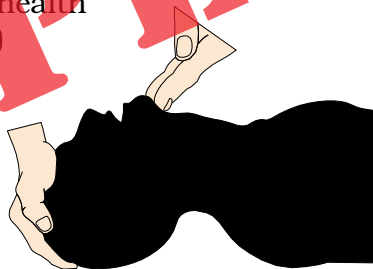
Start with patients who need immediate medical attention. Direct others to a safe area for further assessment.



Be efficient, or some people may leave to seek help elsewhere before you can give them directions. For example, some incidents pose so little risk that it's safe for people to go home rather than inundate local hospitals. Allow people to self-decon on scene if appropriate. Consider whether emergency decon will suffice. If using survey meters to monitor the entire body for residual contamination isn't practical during mass decon, consider monitoring just the critical areas described on page 110.

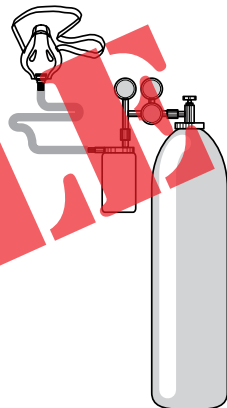
As indicated in the last chapter, signs and symptoms of radiation exposure usually don't appear for several hours. Sometimes it can be days or weeks, depending on type, route, and amount of exposure. **Therefore, patient assessment and emergency treatment should focus first on other potentially more serious conditions.**

Are patients suffering from other health effects (e.g., toxicity or corrosivity) associated with the radioactive material? Have patients been injured by the blast from a "dirty bomb"? The basic principles of patient care don't change for a radiation incident.



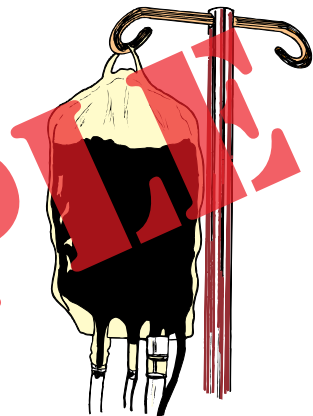
Provide basic life support as needed:

- Oxygen administration
- Suctioning the airway
- Artificial respiration
- CPR
- Control of external bleeding
- Treatment for shock
- Treatment for other injuries
- Monitoring of vital signs
- Reassurance
- Transport to a medical facility



Provide advanced life support as appropriate:

- Cardiac monitoring
- Intubation
- Intravenous (IV) therapy
- Other drugs based on presenting signs and symptoms and local protocols



Specific treatment is best determined by doctors specializing in radiation health effects.

Medical treatments available to cleanse the body of radioactive materials have limited application. For example, potassium iodide (KI) can protect against thyroid cancer caused by internal contamination with iodine-131, but it offers no protection to other parts of the body or against other radioisotopes.



If for any reason you need to transport contaminated patients, protect the ambulance:



- Wrap patients in disposable blankets.
- Stow unneeded equipment and close compartment doors.
- If appropriate, cover or wrap equipment with plastic.
- Decon or discard contaminated equipment afterwards.
- Don't put ambulances back in service or release EMTs/paramedics until they have been checked for contamination and are decontaminated as necessary. (Exception: In mass casualty incidents, it's acceptable to keep ambulances in service until all contaminated patients have been transported.)

Transport patients to a medical facility capable of handling radiation accident patients.

Any hospital should be able to provide the necessary initial care. However, hospitals vary in their ability to provide continued care for acute radiation sickness. They also vary in how well equipped they are to handle patients who have not been fully decontaminated. Coordinate with the facility before transporting patients so that medical personnel can prepare.



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*.



The principles of time, distance, and shielding are intended to prevent both internal and external exposures. However, **if you've had an internal exposure to radioactive materials** (e.g., from inhalation, ingestion, or contamination of an open wound), **your body remains**



exposed until that radionuclide either is eliminated from the body or decays to a stable isotope. Alpha and beta emitters are the most hazardous because alpha and beta particles can transfer ionizing energy to surrounding tissue, damaging DNA or other cellular material and leading to an increased risk of cancer.

Radiation doses are directly proportional to length of exposure, so **keep your exposure time to a minimum.**

If you know the dose rate present (R/hr or mR/hr), you can calculate how long you can safely stay in the area. (See pages 57 and 58 for details.)

If you don't know the dose rate present, spend as little time in the area as possible. You don't have to panic, but neither should you expose yourself unnecessarily. For example, you can take time to safely extricate a patient, but don't linger in the hot zone once extrication is complete.



**A good incident management strategy
can help you minimize exposure time:**

- Establish clear objectives before entering the hot zone, and clearly communicate the objectives to all personnel.
- Plan your activities carefully so they can be completed as quickly and safely as possible.
- Assign someone to keep track of the time personnel spend in the hot zone.
- If operations in the hot zone will be extended, rotate personnel through the area to limit individual exposure.

See Chapter 10 for more information on radiation incident management.

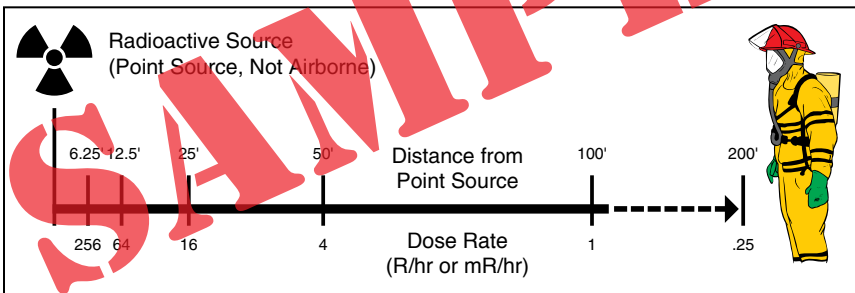
Limit patient care performed in the hot

zone to maintaining an open airway, controlling profuse bleeding, and immobilizing the cervical spine as needed. Delay further care until you get to an area of relative safety. When patients and responders are still in danger, it's best to use a “load and go” approach.

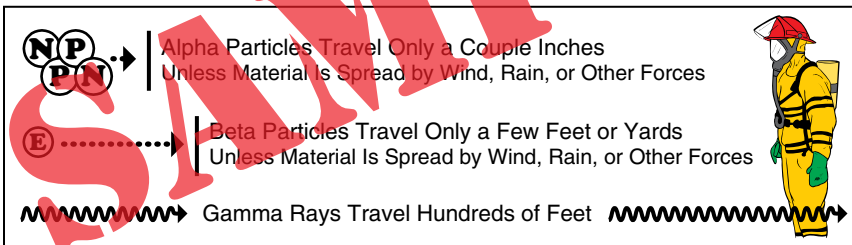


If responders or patients have become contaminated, ensure they are decontaminated as soon as practical. (See Chapter 5.) Remember, serious medical concerns take precedence over decon. However, early decon is part of reducing exposure time.

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.



Use the current edition of the *Emergency Response Guidebook* (ERG) to **determine appropriate isolation and evacuation distances**. Guides 161 through 165 in the ERG2004 recommend 75 feet (25 meters) for initial isolation, 330 feet (100 meters) for downwind evacuation on a large spill, and 1000 feet (300 meters) for initial evacuation when a large quantity of radioactive material is involved in a major fire.



Confirm safe distances by monitoring the atmosphere, particularly if radioactive materials are airborne or if they have been dispersed over a wide area.

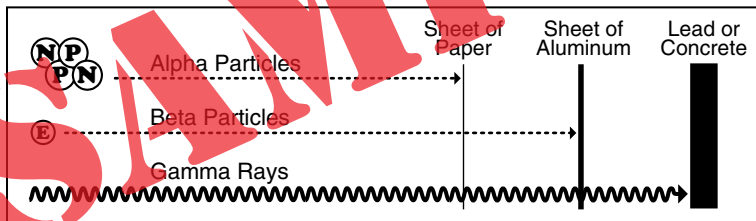
Use common sense when establishing isolation zones.

It's appropriate to err on the side of safety if you are unsure of the risks. However, incidents involving dangerous levels of radiation are rare, and releases are uncommon, even under accident conditions, due to the sturdy packaging. So, seldom is it necessary, for example, to shut down a freeway in both directions, severely impacting the entire community.

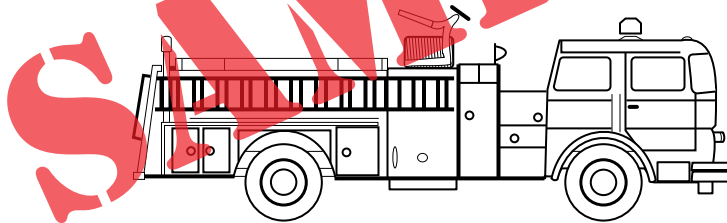


Appropriate shielding will help reduce your exposure.

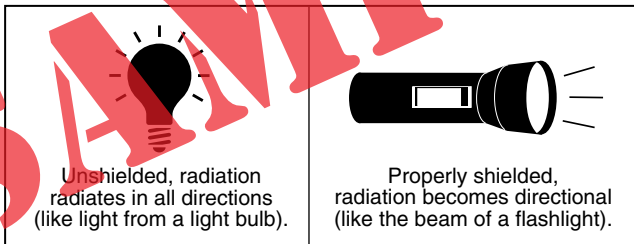
The relatively large alpha particles are stopped by shielding as thin as a sheet of paper. It takes heavier shielding, such as a thick piece of aluminum or an inch of wood, to stop beta radiation. Gamma radiation is so penetrating that far denser shielding, such as several inches of lead or concrete,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



Although lead is the best shield against gamma rays and x-rays, it is generally not practical for emergency operations. However, you can improvise by taking advantage of **shielding available at the scene**. For example, position yourself behind fire engines, buildings, or hills when not directly involved in hot zone operations. Even when working in the hot zone, you can approach from behind vehicles versus move in a direct line of sight.



Radiation can be directional, like the beam of a flashlight. So if a package is breached but the radioactive source is still contained within the package, radiation will be projected in the direction of the breach. Any radiation detected in another direction should be within normal limits of what is permissible at the surface of the package and from 1 meter (3 feet) away.



Personal protective equipment (PPE) also provides some shielding. **Firefighters should wear structural firefighting clothing and SCBA to enter the hot zone.**

This provides full protection from alpha particles. It also protects against inhalation or ingestion of beta particles. Although some beta radiation may penetrate protective clothing, the clothing does reduce the exposure potential. (Again, one can use the flashlight analogy. Light from a flashlight will penetrate clothing, but it will be less strong on the other side.) Structural firefighting clothing will not protect against penetrating radiation such as gamma rays and neutron particles.



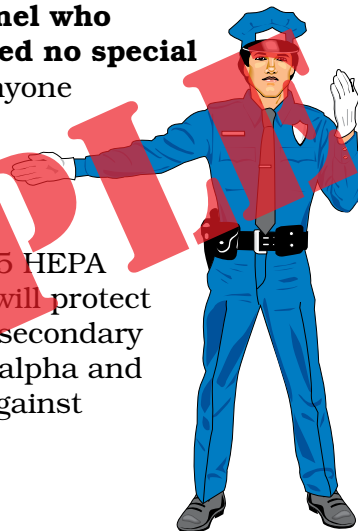
EMS personnel do not need special protective clothing if patients have been thoroughly decontaminated.

However, if that is not the case, EMS personnel should, if possible, wear a long-sleeve uniform, gloves, hood or hair cover, eye protection, shoe covers, and a face mask (N-95 HEPA filter or equivalent). The clothing will protect against inhalation, ingestion, and secondary contamination (skin contact) with alpha and beta emitters. It will not protect against radiation penetration. The best protection is to ensure that contaminated patients are thoroughly decontaminated once more serious injuries are cared for.



Police officers and other personnel who don't enter the hot zone also need no special protection clothing.

However, anyone who must handle contaminated people or evidence should wear a long-sleeve uniform, gloves, hood or hair cover, eye protection, shoe covers, and a face mask (N-95 HEPA filter or equivalent). The clothing will protect against inhalation, ingestion, and secondary contamination (skin contact) with alpha and beta emitters. It will not protect against radiation penetration.



Finally, as with any hazardous material, **do not eat, drink, or smoke** in the incident area. Wash hands thoroughly before eating, drinking, or smoking.



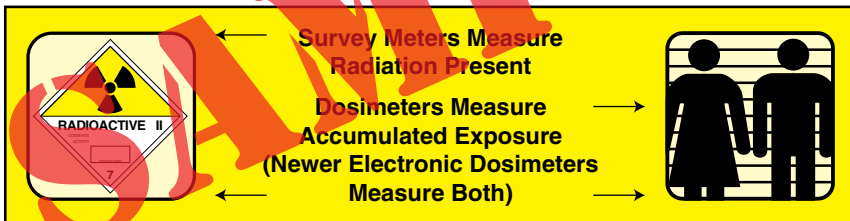
Chapter 7

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.)



To provide an analogy, the **survey meter is like a car speedometer** that identifies how fast you are driving at a given point in time. A **dosimeter is like a trip odometer** that tells you how far you have traveled since the journey began. (Electronic dosimeters capable of monitoring both accumulated dose and dose rate are like a combination odometer and speedometer.)



Both types of meters provide vital information needed by responders at a radiation incident.

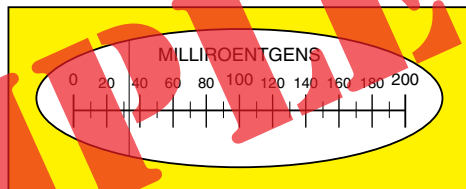
There are two main types of dosimeters. The first is a badge type, the predominant technologies being **thermoluminescent dosimeters (TLD) and film badges**. These dosimeters are used to create official exposure records for radiological workers. They may or may not be provided to emergency responders at a radiation incident. Regardless, these dosimeters cannot be read by the wearer; they must be processed by a TLD or film laboratory (preferably the one from which they were obtained).



Direct reading (self-reading) dosimeters allow response personnel to monitor their own accumulated exposure during an incident rather than have to wait for lab results or to calculate approximate exposures based on survey meter readings and length of exposure. Dosimeters measure accumulated exposure to gamma and x-ray radiation. Pocket optical dosimeters and their required chargers (left) are older technology. Electronic dosimeters (right) are a more recent development.



Pocket optical dosimeters measure accumulated exposure in roentgens (R) or milliroentgens (mR). Exposure is indicated by a vertical hairline that moves across a fixed horizontal scale. The indicator can be viewed through a lens at one end of the dosimeter when pointing it toward a light source (other than the sun). Pocket optical dosimeters can be very difficult to read when wearing full-face respiratory protection. They can be shock-sensitive, which affects the accuracy of any reading. And they lack any alarm mechanism to alert users when defined set points have been reached.



Electronic dosimeters measure accumulated exposure in roentgens or milliroentgens. Some measure in microroentgens (μR)—usually reflecting background levels.

With the digital display, these dosimeters are more accurate and easier to read than are pocket optical dosimeters. Some measure both dose (accumulated exposure) and dose rate (R/hr). They have the added advantage of programmable alarms that can alert the wearer when a specified dose or dose rate is reached and alarm again at a higher action level.



Dosimeters are designed to be used by a single

individual. Badge type dosimeters must not be traded with other responders under any circumstances. A direct reading dosimeter may be handed off to another responder once your mission is complete and the dosimeter reading has been recorded.



To ensure accurate readings with a direct reading dosimeter, zero the unit before use (unless you are monitoring your accumulated exposure over multiple shifts or missions). Record both the starting and ending dosimeter readings on an appropriate exposure log.

Prepare the dosimeter for use. Each dosimeter is different, so it's essential to be familiar with the manufacturer's instructions. The following are only **general reminders**:

- Be sure the dosimeter has been properly calibrated and is fully charged or has fresh batteries.
- Zero the dosimeter.
- Clip the dosimeter to outer clothing as directed by the manufacturer (usually to the upper torso).
- Periodically read the dosimeter to monitor your exposure when working in a radiation environment.

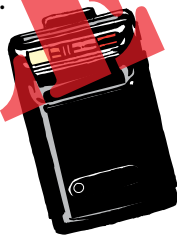


An electronic dosimeter capable of measuring dose rate (R/hr) has added value for emergency responders. When worn as part of the daily uniform, it **can alert the user to higher-than-normal radiation levels at any incident**, whether one suspects radiation or not. It works continuously and doesn't require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



Some electronic dosimeters can do double duty as a survey meter. They can be used to verify readings on a survey meter (described on the following pages), so responders aren't relying on a single instrument. If the incident extends over a large area, as might happen in a "dirty bomb" scenario, electronic dosimeters can supplement available survey meters, allowing responders to monitor more areas simultaneously. Procedures vary nationwide, but some experts consider it acceptable—in the initial response phase, when available equipment is limited—to use electronic dosimeters to monitor dose rate in the hot zone while keeping survey meters with contamination detection capability in the decon area to frisk patients and responders exiting the hot zone.



Survey meters are no longer limited to the civil defense meters that still dominate the field. The vast array of detection equipment is beyond the scope of this book. Instead, we'll focus on some important principles that apply to survey meters in general.

The most sophisticated (and expensive) instruments are capable of identifying specific radioisotopes. Most agencies won't have this equipment or the training necessary to operate it properly, but it can be brought to the scene by county or state radiological officers or by personnel from the EPA, the DOE Radiological Assistance Program, the National Guard Civil Support Teams, or similar resources.



Although survey meters can't identify specific radioisotopes, they will confirm that radiation is present and, subject to some of the limitations highlighted in this chapter, will also indicate *how much* radiation is present.



Measurement devices are used to establish control zone boundaries, control personnel exposure, assess package integrity, and locate sources of radiation.

Contamination detection devices are used to locate contamination on personnel and equipment and to determine the effectiveness of decon.



Know the limitations of your equipment.

No meter can detect all types of radiation effectively. Many meters are also limited in the levels they can detect. For example, the CD V-715 survey meter (top) measures high-level (>50 mR/hr) gamma radiation only, whereas the CD V-700 (bottom) measures low-level (<50 mR/hr) gamma and beta radiation.

Some experts consider civil defense meters less precise than meters based on newer technology. But if properly calibrated—an annual requirement for all radiation detectors—they're still a useful tool for responders.

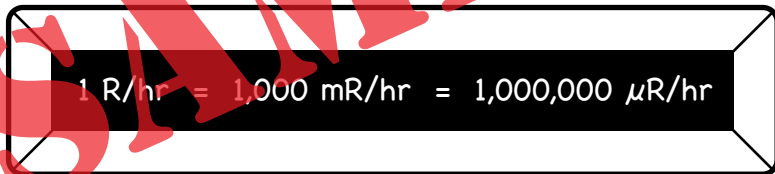


Understand how to adjust the equipment based on type of radiation. For example, the probe of the CD V-700 (left) detects both gamma and beta radiation with the shield open and gamma only with the shield closed. Other detectors, such as the Ludlum unit below right, have two probes: a gamma scintillator for area monitoring and an alpha beta gamma pancake probe for frisking (checking patients and responders for contamination).

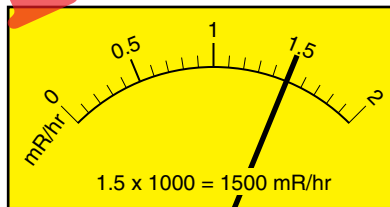
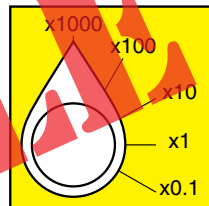


Understand the units of measure, and read the meter correctly.

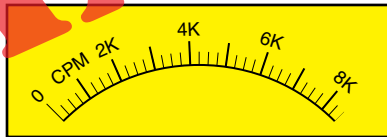
One of the most common mistakes people make is misinterpreting the reading. If you fail to read your meter correctly, you might either turn a minor problem into a major incident or inadvertently overexpose yourself and other responders. Remember: One roentgen (R/hr) equals 1000 milliroentgens (mR/hr)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



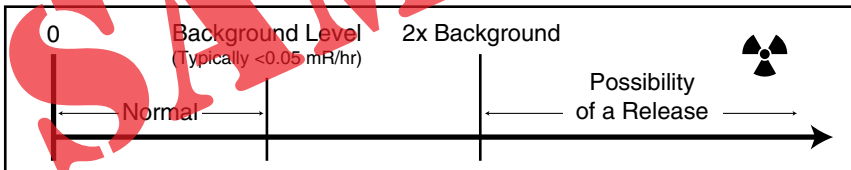
Know what scale you are reading. If your meter is set to the x1 (times 1) scale, the exposure rate is what you see on the meter. However, if the selector switch is set to x0.1, x10, x100, or x1000, the meter readings must be multiplied by 0.1, 10, 100, or 1000 respectively. For example, if your meter 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.



Many survey meters display results in counts per minute (cpm). It takes a subject matter expert to convert counts per minute into more familiar units of measure. So for practical purposes, consider counts per minute a reference unit to identify whether or not contamination is present. Some response from the meter is normal due to background radiation (see next page) and should be expected. Noticeable increases (more than two to three times background) should be considered a positive indication of contamination.



Some background radiation is normal. It's *typically* less than 0.05 mR/hr, but that can vary with elevation, geology, etc. Knowing the normal background levels in your area can help you quickly determine the likelihood of a problem. If meter readings exceed two or three times the normal background level, suspect that radioactive materials are present, and respond accordingly. (Consult with your subject matter experts to develop pre-determined action levels.)



If you've already recorded normal background levels in your area (see next page), you'll be ahead of the game. But one way or another, once you've prepared your survey meter for use, you'll need to **establish and record the background radiation level** in a nonimpacted area.



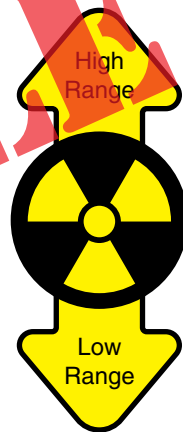
Subsequent meter readings are evaluated relative to this background level. Decisions are often made based on specific numbers (e.g., establishing an initial perimeter where radiation levels are at or below 2 mR/hr above background). However, it may be appropriate to think in multiples (e.g., to decon people or surfaces if readings exceed two or three times background).

Use this space to **record normal background radiation levels** in your area. Don't wait for an incident to occur.

Location	Radiation Level

Because of the limitations inherent in the equipment, **it may be necessary to use more than one detector.** Ideally, you should have the capability to monitor for alpha, beta, and gamma radiation.

You must also be able to monitor both high and low levels of gamma radiation. A high-range meter is critical for detecting dangerous levels of radiation. In that environment, a low-range detector may become saturated above its top limit and give false low readings or become nonoperable. Conversely, a high-range detector may not be sensitive enough to pick up low levels of radiation, resulting in exposures that could otherwise be avoided.



Know how to improvise if you don't have a full range of detection equipment. (Note: This is not a recommendation to avoid purchasing the right equipment. It's something to fall back on while waiting for other responders to arrive with the right tools for the job.)

Most radioactive materials emit more than one type of radiation. So, for example, if you have a meter capable of detecting gamma radiation but not alpha, it should alert you to the presence of gamma radiation from a material that gives off both alpha and gamma radiation. This is akin to recognizing cross sensitivities with other hazmat monitoring equipment.



Prepare the meter for use. Each survey meter is different, so it's essential to be familiar with the manufacturer's instructions. The following are only **general reminders**:

- Attach and adjust the probe (if applicable).
- Be sure the meter has been properly calibrated and that it has fresh batteries.
- Verify that the meter is on, the range selector switch is set to the lowest (most sensitive) scale, the audio can be heard (if applicable), and a visual response registers on the meter.
- Zero the meter (if applicable).
- Perform pre-operational checks per the instruction manual.
- Allow adequate warm-up time.
- Establish the background level in a nonimpacted area.





If the meter is not intrinsically safe, monitor for flammable atmospheres before taking the survey meter into the hot zone.

When using measurement equipment (e.g., to assess the scene), start from a safe distance and slowly move closer if appropriate. Relay readings to responders up-range who can record and interpret the results.



When using contamination detection equipment (e.g., to monitor patients),

keep the probe no more than an inch (preferably half an inch) from the surface. Move the probe slowly (one to two inches per second) and methodically. An increase in the instrument chirping and/or the digital readout are indicative of contamination. (See pages 108 through 111 for more information on patient monitoring. The same guidelines will apply to monitoring responders leaving the hot zone.)



Chapter 8

Radiation and Terrorism

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



Approximately 70% of terrorist events involve the use of conventional explosives and improvised explosive devices (IEDs). The components are comparatively easy to obtain, make, and deploy, and the effects generally produce the desired results. So for most terrorists, there's no need to explore using other weapons of mass destruction. However, we can't ignore the possibility of a terrorist event involving radioactive materials.



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

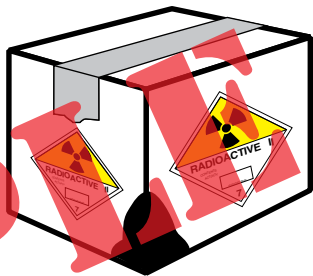
- A hoax or threat, with no actual event
- Planting a radioactive source near intended targets
- Dissemination with a spray device
- Contamination of food and water supplies
- Bombing of a nuclear facility or transportation vehicle
- Use of an improvised nuclear device (IND)
- Use of a radiological dispersal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

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

Keep in mind as you read through these scenarios that **most of the radioactive sources a terrorist might gain access to do not emit life-endangering amounts of radiation.** High-level radioactive sources are too tightly regulated and controlled in many countries to make them easily accessible. That doesn't mean that terrorists couldn't obtain high-level sources. However, if terrorists can create almost as much panic with more easily obtainable low-level radioactive materials (and less risk of getting caught), most will take the path of least resistance.



So many people are afraid of radiation that **a simple hoax** might be enough to terrorize a portion of the population. For example, a damaged box with a radiation label left in plain view in a public place could generate significant concern until emergency responders with radiation detectors determined there was no threat. It's a scenario that's quickly defused by well-trained responders with the right equipment, yet one that has the potential to disrupt normal operations and raise questions about our ability to protect against real incidents involving radioactive materials.





Likewise, **the mere threat of a terrorist attack involving radioactive materials** can cause fear and disruption.

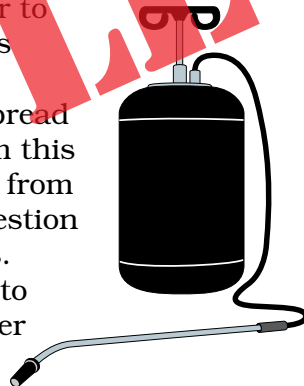
Responders must be able to quickly determine if the threat is credible, how to protect against it if it is, and how to calm public fears if it isn't.

Radioactive materials concealed near intended targets could cause victims to develop radiation sickness. The source would irradiate (but not contaminate) exposed persons until the radioactive material was discovered or until the victims developed recognizable symptoms and someone unraveled the mystery of why. It's a scenario that lacks the immediacy and impact associated with the others, but one that might be employed on a small scale by someone intending to hurt specific individuals.



Dissemination of radioactive materials with a spray device

is another low-tech method that lacks the immediate, dramatic results some of the other scenarios would produce. However, it contains the frustrating complications of delayed discovery similar to those in a biological agent attack. There's also a much greater danger of secondary contamination as victims unknowingly spread the radioactive materials. Protection from this scenario is highly dependent on vigilance from all citizens. People must be willing to question unusual spraying and to alert authorities. And emergency responders must be able to monitor for radioactive materials and other contaminants.



Contamination of food and water supplies

isn't a scenario most experts talk about.

But if a religious cult can contaminate salad bars with Salmonella (Oregon, 1984), why can't someone sprinkle a radioactive dust or powder on foods instead? The relative difficulty of

obtaining radioactive materials, combined with the inability to produce immediate, dramatic results, makes the scenario unlikely, but not impossible. Protection from this scenario requires the same kind of vigilance from citizens as does protecting food and water supplies from contamination with chemical and biological warfare agents.

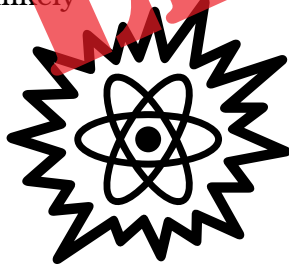


A terrorist might use an ordinary explosive device to **damage a nuclear power plant, a nuclear storage facility, or a vehicle transporting nuclear materials.** In general, nuclear facilities are at less risk because they store high-level radioactive materials in well-protected, heavily shielded areas.

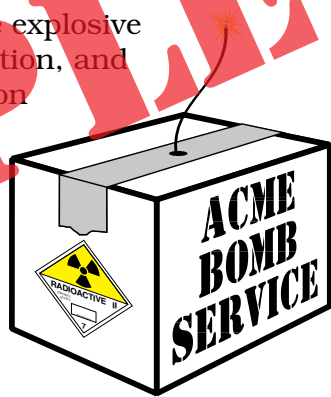


Transportation vehicles are more vulnerable to attack. However, other safeguards are used to protect high-level radioactive materials in transit, including heavy-duty packaging, escorts accompanying the shipment, devices that can immobilize the transport vehicle in a hijack attempt, and continuous satellite monitoring of the transport vehicle.

Use of an **improvised nuclear device (IND)**—be it a nuclear weapon obtained from a nuclear State or a weapon fabricated by terrorists with illegally obtained fissile materials—could cause catastrophic loss of life and spread high levels of contamination over a very large area. IND scenarios have long been considered unlikely because of the extreme difficulty of acquiring a fully functional nuclear weapon. But the escalation of terrorism throughout the world makes it foolish to rule out the possibility. A greater threat, however, is the use of smaller nuclear bombs, such as the suitcase and attaché bombs built years ago and not well accounted for today.



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.



The tremendous heat generated by an explosion from an RDD or IND causes an updraft that draws dirt particles and other debris into the air. The dirt and debris can become coated with the radioactive materials. When the contaminated dirt and debris eventually fall back to earth, it becomes part of the **radioactive fallout**. The contamination may be minimal with an RDD (see pages 172 and 173). It's likely to be extensive with an IND.



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.

The Department of Homeland Security highlights five **major differences between RDD or IND incidents and nuclear power plant accidents**. These present significant challenges for emergency responders.

- An IND incident is likely to be **more severe** (higher radiation levels and larger radius of damage) than a nuclear power plant accident, where protection and containment measures exist. (RDD incidents won't be as severe as IND incidents.)
- RDD and IND events may involve a **delay in identifying** the material and its hazards, whereas that information is part of a nuclear power plant's emergency plan.



- An RDD or IND incident will likely have **no warning** and involve a release of short duration, whereas a nuclear power plant accident is more likely to involve a protracted release preceded by enough warning to begin protecting the public.
- Terrorists are likely to target **large populations or critical infrastructure**, whereas many nuclear facilities are located in more remote areas to reduce the risk to life, the environment, and property.
- Most terrorist targets are likely to be **less prepared** than nuclear facilities and surrounding communities.



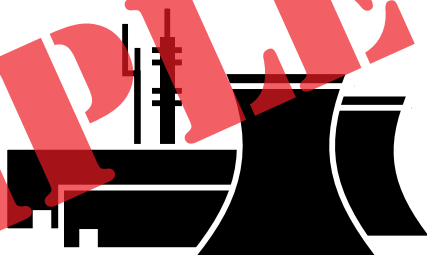
A nuclear power plant accident, as described in the next chapter, doesn't produce that "mushroom cloud" and radioactive fallout associated with a nuclear blast. So when one considers fallout and all the other factors presented on the previous pages, it's easy to see that **IND incidents have a far greater potential to do damage** than do most nuclear power plant accidents.



Chapter 9

Nuclear Power Plant Accidents

The worst-case scenario at a nuclear power plant is one involving the release of fission products originating in the fuel rods.



While the idea of a catastrophic nuclear power plant accident is frightening, such a scenario is unlikely due to all the built-in safety features, including improvements made after the worst nuclear power plant accident in U.S. history (Three Mile Island, Pennsylvania, March 28, 1979).

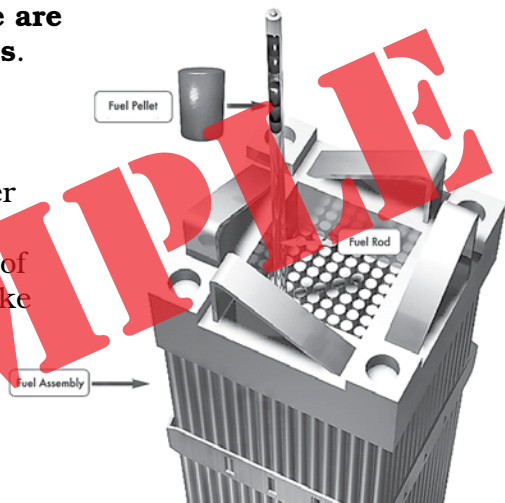
Most accidents don't result in a release of radioactive materials.

Of those that do, it's uncommon for the public to be exposed, thanks to the multiple barriers used to prevent a release to the atmosphere.



The first line of defense are the fuel rods themselves.

About 99% of the fission products remain trapped in the ceramic pellets of a fuel rod. The remainder is contained within the cladding (the outer layer of the fuel rod). It would take a breakdown of the fuel cladding due to overheating for fission products to be released from the fuel rods.



Within the reactor vessel are several redundant cooling systems designed to prevent overheating under normal and severe accident conditions. It would require a failure of all these systems to generate a meltdown or severe damage to the reactor core.

Should the fuel cladding, reactor vessel, and all other redundant safety systems fail, there's a third barrier—the **containment building** constructed of high-density, reinforced concrete up to 6 feet (1.8 meters) thick.



The containment building is designed to withstand not only a severe power plant accident, but also earthquakes, hurricanes, tornadoes, airplane crashes, and other foreseeable disasters.

The **effectiveness of containment buildings** was clearly demonstrated in the Three Mile Island accident, where only a small amount of fission products was released, despite severe core damage and failure of the primary coolant system.

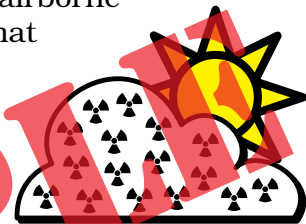


Redundant monitoring and alarm systems guarantee that **most foreseeable accidents would be preceded by enough warning** to notify the public and provide protective action instructions.

Although emergency plans for each site will vary based on the circumstances and local conditions, a severe accident would typically prompt **pre-release evacuation** of people within 2 to 3 miles (3 to 5 kilometers) in all directions and up to 10 miles (16 kilometers) downwind. Others in the vicinity should shelter in place. After a release, appropriate distances should be confirmed through radiological monitoring.



A radioactive plume is similar to any airborne cloud of hazardous materials, except that the gases, vapors, and/or particles are radioactive rather than flammable, corrosive, etc. Potential health effects were covered in Chapter 4. Appropriate protective actions can prevent inhalation exposure and contamination of one's skin and clothing.



State and local officials will need to perform subsequent testing to determine if radioactive materials have been deposited on the ground, where they can present further risk, such as by being consumed after entering the food chain via grazing animals or plant uptake.

Nuclear power plants and surrounding communities are required to have **emergency plans and regular drills**. If you live or work near a nuclear power plant, you should be familiar with those plans. This book is a valuable supplement, but it's not a substitute for being familiar with your community's plans or participating in drills and other training.



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 472—the standard for hazmat response (published by the National Fire Protection Association).



Look for clues that hazardous materials may be present. Remember, radiation cannot be seen, smelled, tasted, heard, or felt. So you become more dependent on other clues:



- Occupancies or locations where radioactive materials are likely to be used, stored, or transported
- Facility plans
- Packaging specifically designed for radioactive materials
- Labels, placards, and other marking systems
- Shipping papers and material safety data sheets (MSDS)
- Information from a responsible party
- Dosimeter alarms or other readings on radiation detection equipment

Call for trained personnel. The first of what may be several phone calls should be to **911** (or the appropriate number in your area). Provide the following information:



- Location of the incident
- Type of hazmat incident (fire, spill, exposure, etc.)
- Material involved (if known)
- Whether anyone was injured or exposed
- Approximate size of the fire or release
- Environment affected (air, land, or water)
- Information on product spread and safe approach
- Whether criminal or terrorist activities are suspected
- Actions being taken
- Your name and the phone number you are calling from

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 ERG2004 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

If radiation is not the primary hazard, adjust the isolation distances on the previous page. Remember, this book focuses on radiation, but there can be many hazards, chemical and otherwise, at a hazmat incident. Or there may be multiple products involved or threatened.



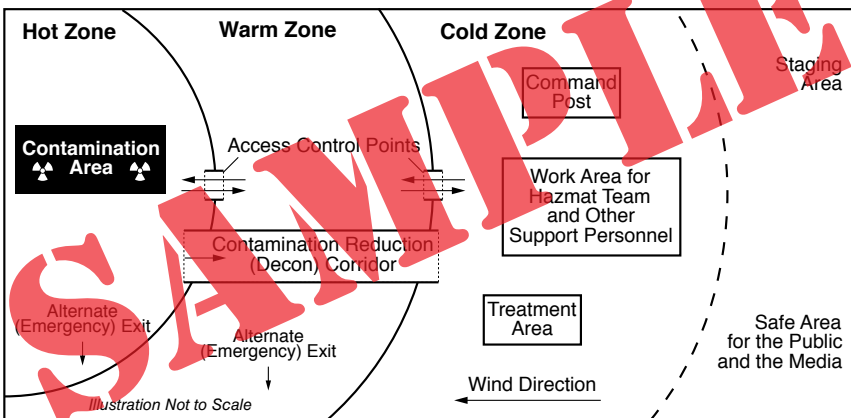
If you have monitoring equipment (radiation detectors, oxygen meters, combustible gas indicators, etc.), use these tools to determine safe distances. Use the *Emergency Response Guidebook*. Above all, use common sense, and when in doubt, err on the side of safety.

Assist in setting up control zones as appropriate.

Control zones should be established based on technical reference materials and atmospheric monitoring. Zones are usually determined by hazmat teams, but first responders can assist once the appropriate distances are known.

Zone	Description
Hot (Exclusion) Zone	Area around release where contamination exists. Entry requires use of proper PPE.
Warm (Contamination Reduction) Zone	Decon area. Requires use of proper PPE once contaminated people or equipment enter zone.
Cold (Support) Zone	Clean area for command and support functions. Special PPE is not required.

Shown below is a **generic control zone layout** that can be modified to meet the needs of the incident.



Make mandatory notifications if the incident involves a reportable quantity of the material and if the responsible party has not yet done so. Reporting requirements and resources vary from state to state, but they generally involve the four levels below. These resources often help make other notifications.



Agency	Phone Number
Fire department having jurisdiction	911 or
Local emergency planning committee (LEPC)	
State and/or tribal notification center	
National Response Center (NRC)	(800) 424-8802

Use this space to list **other important resources** you can call for assistance with radiation incidents.

Name/Agency	Phone Number
CHEMTREC	(800) 424-9300

A transportation incident (including loading, unloading, and temporary storage) **is reportable if there's a fire, breakage, spillage, or suspected contamination involving radioactive materials** or if any of the following occurs as a direct result of a hazardous material:

- Someone is killed or receives an injury requiring admittance to a hospital
- The general public is evacuated for one hour or more
- A major transportation artery or facility is closed or shut down for an hour or more
- The flight plan or routine of an aircraft is altered

See 49 CFR 171.15 for complete requirements.

If in doubt about the reporting requirements (or anything else about handling the incident), **consider calling your state or local radiation officer** for guidance.



Reporting requirements for radiation incidents differ slightly from those for other hazmat incidents. Reportable quantities for radionuclides are based on activity (measured in curies or becquerels), not weight or volume. It's mandatory to report the loss, theft, or unlawful diversion of some radionuclides, because of their potential use as WMDs. Other reporting requirements are based on exposure levels, contamination levels, how long an area might be restricted due to contamination, or failure of equipment designed to prevent a release.

Size up the incident from a safe location to determine the magnitude of the problem in terms of potential outcomes. Your size-up should include an assessment of:



- Hazardous material or WMD involved (identity, form, and amount)
- Condition of containers
- Surrounding conditions that can affect the risks involved and the way you handle the incident
- Risk of injury or secondary contamination to patients and response personnel
- Number of patients and need for decon and medical care
- Signs of criminal or terrorist activity

Correctly identify the product. Your safety depends on it. Something as simple as a spelling error can send you in the wrong direction and endanger everyone involved. Pay particular attention to the following:

- Name (correct spelling) and numbers
- Form (solid, liquid, gas)
- Concentration

Often this information is obtained from labels, MSDSs, or shipping papers. However, it may be necessary to verify product identity with facility managers, shippers, manufacturers, CHEMTREC, or other resources.



Use at least three information sources for product identification and hazard assessment. If you find conflicting information, check additional reference sources. When in doubt, assume the worst and err on the side of safety. If the specific radioisotope is not known (for example, in a terrorist event), follow the general guidelines for dealing with radioactive materials. Isotope identification can be done by subject matter experts later.



Remember, although the focus of this book has been the dangers of radiation, radioactive materials may have other significant hazards. For example, they may be flammable, toxic, or corrosive. These hazards must also be considered when planning your response.

Predict the behavior of the material and its container based on information from the *Emergency Response Guidebook*, MSDSs, shipping papers, and input from the shipper, manufacturer, facility personnel, or other reliable resources. Try to identify the following:



- Chemical and physical properties (in addition to radioactivity)
- Types of stress on the container and its contents
- Ways the container can breach
- Ways the containment system can release its contents
- Dispersion pattern expected upon release
- Exposure potential (short-term to long-term)
- Health and physical hazards

Estimate the potential harm to the best of your ability. Evaluate the following:

- Size of the endangered area
- Quantity of material already released and concentrations in the endangered area
- Quantity of material remaining in breached container
- Number and type of exposures (people, the environment, and property) in the endangered area
- Extent of physical, health, and safety hazards
- Potential outcomes to life, the environment, and property
- Potential for secondary events
- Worst-case scenarios

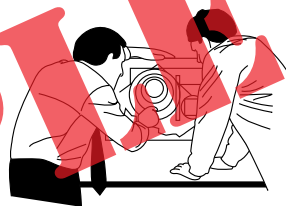


Determine your response objectives (strategy). First responders, by definition, are limited to defensive actions. However, depending on the material involved, the nature of the incident, and the scope of your responsibilities, you may be able to implement limited offensive actions.

Actions	Description
Nonintervention	Appropriate if unsafe to do anything, the incident poses no risk to life, or there is a lack of adequate resources to safely and effectively deal with the problem.
Defensive	Done to restrict, slow, or redirect the spread of a material and keep it as close to the source as is safe and practical.
Offensive	Done to stop the release.

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



Implement the planned response

to favorably change the outcomes consistent with your local emergency response plan and your agency's SOPs.

- Maintain scene control by enforcing control zones, performing emergency decon as needed, and maintaining effective communications.
- Follow the incident command system (ICS).
- Perform defensive control measures identified in your plan of action.
- Immediately alter, suspend, or terminate unsafe actions or conditions. Adjust the plan as needed to ensure safety.



Fires involving radioactive materials were not addressed in previous chapters, so let's look at them in the context of incident management. According to the *2004 Emergency Response Guidebook*:

- Fire control is a higher priority than measuring radiation levels.
- Radioactivity does not change flammability or other properties of radioactive materials.
- The presence of radioactive materials will not influence fire control processes and should not influence the selection of techniques.



General guidelines for dealing with fires involving radioactive materials include:

- Move undamaged packages away from the fire if you can do so safely. Do not move damaged packages.
- Use dry chemical, carbon dioxide, water, or foam on small fires.
- Use flooding amounts of water (fog stream) on large fires.
- Contain contaminated runoff.
- Minimize overhaul once fire is extinguished.
- Contact your state or local radiological officer or health department for assistance.



Implement protective actions as needed. Guides 161 through 165 in the ERG2004 recommend an initial downwind evacuation distance of 330 feet (100 meters) for large spills and an initial evacuation distance of 1000 feet (300 meters) in all directions for a major fire. However, additional protective actions may be required.

Evacuation is best when there is time to accomplish it safely, the benefits outweigh the risks, or in-place protection won't adequately protect people. In-place protection (shelter-in-place) is recommended when the risks are minimal. It may be needed as an interim measure for people who can't be evacuated right away.



The U.S. EPA *Manual of **Protective Action Guides** and Protective Actions for Nuclear Incidents* (also known as the *EPA PAG Manual*) recommends implementing protective actions as summarized below. These guides (sometimes referred to as PAGs) are *nonregulatory*. They represent approximate levels at which the protective actions are *justified*, but they give emergency managers flexibility to weigh this against other chemical and biological hazards, unique characteristics of the incident, potential for long-term contamination, and the logistics of implementing protective actions.

Action	Protective Action Guide
limit emergency worker exposure	5 rem (except where unavoidable) *** See page 47 for more info ***
shelter or evacuate public	1 to 5 rems projected dose (should normally begin at 1 rem)

Decontaminate people and equipment as needed.

As indicated in Chapter 5, serious medical problems take precedence over radiation concerns such as monitoring and decon, because radiation injuries are not immediately life-threatening, whereas other injuries can be. However, if decon is needed, it should be done as soon as practical to avoid spreading the contamination. Refer to Chapter 5 for information on patient decon.



Properly dispose of any contaminated PPE and other equipment that cannot be adequately decontaminated.

Evaluate your progress throughout the incident to make sure your efforts are successful and that everyone is operating safely.

If there is nothing you can do to mitigate the incident and it looks like conditions may deteriorate, if the problem has intensified, or if the scene has become unsafe, pull back and reassess the situation. Never be afraid to appear foolish for retreating. Your first priority is to protect yourself and other people around you.



Preserve evidence as much as possible to the extent that it does not hamper emergency operations. Preservation of evidence is vital where criminal activities are suspected but can be just as important in accidental events.



- Secure and isolate areas where evidence is located.
- Touch as little as possible. Don't disturb the scene more than is necessary to ensure your safety, treat the injured, and protect the evidence.
- If you must disturb evidence, pay close attention to what you see and do. Document your activities afterwards.
- When cutting through clothing to treat patients, try to preserve holes or other evidence on the clothing.
- If possible, take photographs before moving anything.

Collect evidence as appropriate. Ideally, evidence collection should be done by people with special training. Evidence can easily be contaminated or rendered inadmissible in court if not handled properly.



- Wear proper PPE to ensure your safety.
- Follow local protocols.
- Obtain a search warrant if needed.
- Use multiple forms of documentation (notes, sketches, voice recordings, photos, video tape, etc.) as appropriate.
- Compile a thorough evidence log, and tag each item of evidence to correspond with your log.
- Use proper evidence collection containers.
- Maintain an unbroken chain of custody.

Facilitate cleanup and disposal.

Anything from the incident that must be disposed of, whether it be the spilled material itself or anything contaminated by the material, should be considered hazardous waste until proven otherwise. Hazardous waste must be disposed of in accordance with all applicable federal, state, and local laws. Disposal generally must be done by a licensed waste hauler.



Properly **terminate the incident** to ensure the safety of response personnel, to facilitate transition from the emergency phase to the restoration and recovery phases, and to identify lessons learned that may benefit emergency responders at future incidents. Terminating the incident generally involves three components:



- **Debriefing** ... important information responders should know before leaving the scene
- **Post-Incident Analysis** ... reconstruction of the incident to establish a clear picture of events, ensure accurate documentation, and lay groundwork for any follow-up
- **Critique** ... recommendations for improving the emergency response system

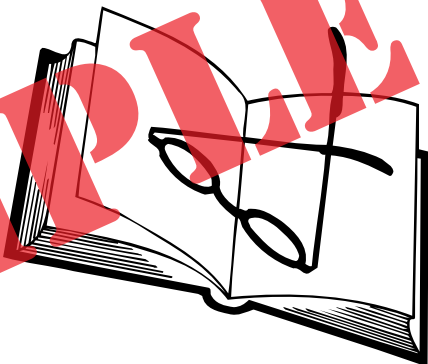
Document the incident. Failure to document properly is one of the most common causes for an OSHA citation. Documentation may include, but is not limited to:



- Your incident action plan (or site safety plan)
- Names, contact information, and incident roles and responsibilities for all response personnel
- Copies of MSDSs and shipping papers
- Diagrams, photos, video, etc.
- Evidence and sample collection logs
- EMS and employee exposure records

Appendix

- Acronyms and Abbreviations
- Index
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- About the Author
- Other Books by
Jill Meryl Levy



Acronyms and Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
AIHA	American Industrial Hygiene Association
ALARA	As Low As Reasonably Achievable
CD	Civil Defense
CFR	Code of Federal Regulations
CHEMTREC	Chemical Transportation Emergency Center
CSI	Criticality Safety Index
CSTI	California Specialized Training Institute
DOE	Department of Energy
DOT	Department of Transportation
EPA	Environmental Protection Agency
ERG	Emergency Response Guidebook
ERG2004	2004 Edition of the Emergency Response Guidebook
HRCQ	Highway Route Controlled Quantity
IAEA	International Atomic Energy Agency
ICS	Incident Command System
IDLH	Immediately Dangerous to Life and Health

Acronyms and Abbreviations (continued)

IND	Improvised Nuclear Device
LC	Lethal Concentration
LD	Lethal Dose
LEL	Lower Explosive Limit
LEPC	Local Emergency Planning Committee
LOC	Level of Concern
MSDS	Material Safety Data Sheet
NIOSH	National Institute for Occupational Safety and Health
NRC	National Response Center
OSHA	Occupational Safety and Health Administration
PAG	Protective Action Guide
PPE	Personal Protective Equipment
Rad	Radiation Absorbed Dose
Rem	Roentgen Equivalent Man
RDD	Radiation Dispersal Device (Dirty Bomb)
TLD	Thermoluminescent Dosimeter
WMD	Weapons of Mass Destruction

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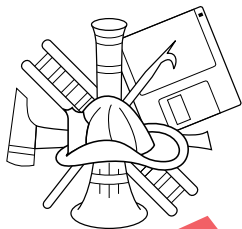
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- Nuclear Energy Institute (<http://www.nei.org>)
- Radiation Emergency Assistance Center/Training Site (REAC/TS) (<http://www.ornl.gov/reacts/>)
- RadMeters4u.com (<http://www.RadMeters4u.com>)
- U.S. Centers for Disease Control (<http://www.cdc.gov>)
- U.S. Department of Energy, Office of Environmental Management, Transportation Emergency Preparedness Program (TEPP) (<http://web.em.doe.gov/otem/program.html>)
- U.S. Environmental Protection Agency (<http://www.epa.gov>)
- U.S. Nuclear Regulatory Commission (<http://www.nrc.gov>)
- World Nuclear Association (<http://www.world-nuclear.org/>)
- World Nuclear Transport Institute (<http://www.wnti.co.uk>)

About the Author



Jill Meryl Levy owns her own business called Firebelle Productions. She is an author and publisher, specializing in books on hazardous materials and more effective writing. She also produces brochures, booklets, and newsletters for fire departments and industry.

Jill has been a volunteer firefighter for the Santa Clara County Fire Department in California since 1980. In 1995 she became a CSTI-certified hazmat specialist and a first responder outreach instructor.



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