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RADIATION EMERGENCIES

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GOAL OF THIS SECTION

- To provide information on nuclear events (e.g., nuclear bomb, improvised nuclear devise)
- To provide information on radiological events (e.g., radiological dispersal device, such as a dirty bomb; sabotage of a nuclear power plant)

WHAT THIS SECTION INCLUDES

- Explanation of the differences between nuclear and radiological events and how they might affect people
- Sources for additional information
- How to lessen the impact of radiation exposure

WHAT THIS SECTION DOES NOT INCLUDE AND WHY

- Extensive detail on radiological emergencies is not provided in this section due to the complexity of the topic.
- Radiological accidents are not covered in detail in this section. However, much of the material in this section would be applicable to radiological accidents (e.g., nuclear reactor issues, a spill of radiological materials, accidents with nuclear weapons).

BASIC FACTS

- **Radiation** is energy moving in the form of particles or waves. Some examples of electromagnetic radiation are heat, light, radio waves, and microwaves. The specific type of radiation discussed in this guide is ionizing radiation.
- **Ionizing radiation** is a very high-energy form of electromagnetic radiation and cannot be detected without specialized equipment.
- **Radioactivity** is the process of spontaneous transformation of the nucleus of an atom, generally with the emission of alpha or beta particles often accompanied by gamma rays. This process is referred to as decay or disintegration of an atom.
  - An **alpha particle** is the nucleus of a helium atom, made up of two neutrons and two protons. Alpha particles generally carry more energy than gamma or beta particles and deposit that energy very quickly while passing through human body tissue. Alpha particles can be stopped by a thin layer of light material, such as a sheet of paper, and cannot penetrate the outer, dead layer of skin. Therefore, they do not damage living tissue when outside the body. When alpha-emitting atoms are inhaled or swallowed, however, they are especially damaging because they transfer relatively large amounts of ionizing energy to living cells.
  - **Beta particles** are electrons ejected from the nucleus of a decaying atom. Although they can be stopped by a thin sheet of aluminum, beta particles can penetrate the dead skin layer, potentially causing burns. They can pose a serious direct or external radiation threat and can be lethal depending on the amount received. They also pose a serious internal radiation threat if beta-emitting atoms are ingested or inhaled.
  - **Gamma rays** are a high-energy electromagnetic radiation. Gamma rays are very penetrating and generally require material such as lead or thick concrete to reduce the exposure. Gamma rays are a serious direct or external radiation threat. They also pose a threat when they are inhaled or ingested. Gamma rays are very similar to X-rays.
  - **Neutrons** are small atomic particles found within an atom's nucleus. Neutrons are a highly penetrating radiation when released by nuclear fission (the splitting of an atom) and are a serious direct or external radiation threat after a nuclear detonation (e.g., nuclear weapon or an improvised nuclear device). These types of radiation incidents are discussed later in this section.

Any or all of the types of radiation described above may be present after a radiological event. Public health officials would determine the specific protective actions that the public should take as soon as the nature of the event is determined by radiological experts.

- **Radioactive material** is material that contains unstable (radioactive) atoms that give off radiation as they decay.
- **Radioactive decay** is the spontaneous disintegration of the nucleus of an atom.
- **Radioactive half-life** is the time required for a quantity of a radioactive material to decay by half.
- **Radioactive contamination** is the deposition of radioactive material (e.g., dirt, dust, debris, liquid) on the surfaces of structures, areas, objects, or people. It can be airborne, external, or internal.
- **Radiation exposure** is not the same as contamination. Exposure occurs when radiation penetrates the body and deposits its energy. For example, when a person has a chest X-ray, he or she is *exposed* to radiation, but he or she is not *contaminated*.

NUCLEAR/RADIOLOGICAL AGENTS—TIMELINE OF SELECTED IMPORTANT EVENTS

1940: Scientists based in Britain first report that the production of a nuclear bomb is possible.

1941: British nuclear weapons research begins.

1943: Americans join the research effort with the "Manhattan Project."

1945: The United States uses two atomic bombs against Japan in World War II.

1957: First full-scale nuclear power plant goes into service in Shippingport, PA.

1968: Treaty on the Non-Proliferation of Nuclear Weapons is developed.

1979: Three Mile Island nuclear power plant near Harrisburg, PA, releases small amounts of radioactive gases into the atmosphere after the power plant's core accidentally overheats and partially melts. There were no deaths or injuries to plant workers or members of the nearby community from this accident.

1986: An accidental chain reaction in the Soviet Union's Chernobyl nuclear power plant, near Kiev, leads to an explosion that releases radiation into the air. The accident kills more than 30 people immediately and prompts the evacuation of 135,000 people as a result of the high radiation levels in the surrounding 20-mile radius.

1987: Four people die of acute radiation sickness and others are sickened in Goiania, Brazil, after two individuals discover radioactive cesium in a canister scavenged from an abandoned hospital. Children inadvertently spread the radiation throughout the community after rubbing the canister's contents on their bodies so they could glow in the dark.

1999: An accident occurs at a nuclear fuel conversion plant in Tokaimura, Japan. The accident was caused by human error circumventing standard procedures. Three workers suffered from acute radiation syndrome (one subsequently died). Other workers and some members of the public were exposed to radiation. Families within the 350-meter perimeter of the site were evacuated and the population within the 10-kilometer radius (300,000 people) were sheltered-in-place for 18 hours.

NUCLEAR/RADIOLOGICAL AGENTS AS WEAPONS

The first step in understanding radiation emergencies is to draw the distinction between a **nuclear event** (like the bomb dropped on Hiroshima, Japan) and a **radiological event,** such as a nuclear power plant incident or a radiological dispersal device (e.g., dirty bomb). In short, a nuclear event involves nuclear fission (splitting of atoms) and a highly destructive explosion that instantly devastates people and buildings because of extreme heat and impact of the blast. A nuclear event typically leaves large amounts of radioactivity behind. On the other hand, a radiological event does not involve nuclear fission but may be accompanied by an explosion and release of radioactivity. A radiological event typically involves the release of less radioactivity than a nuclear event. With both nuclear and radiological events, wind direction and weather patterns can spread radioactivity beyond the immediate incident site.

Four specific radiation incidents will be discussed:

- Nuclear power plant attack
- Radiological dispersal device (e.g., dirty bomb)
- Improvised nuclear device (e.g., suitcase bomb)
- Nuclear weapon

NUCLEAR POWER PLANT ATTACK

- This is a radiological threat that does not involve a nuclear blast.
- Terrorists could attack a nuclear power plant by using explosives, hacking into the computer system, or crashing a plane into the reactor or other structures on site.
- Security measures are in place so that such attempts are likely to be detected early. Also, nuclear power plants have well-established emergency response procedures in place.
- Nuclear power plants are built to sustain extensive damage without releasing radioactive material.
- Theoretically, radioactive materials could escape in some cases and contaminate the surrounding area and the environment.
- Costly and time-consuming cleanup efforts could be required to remove released radioactive materials from the environment.
- Though the death toll and radiation exposure could be limited, the psychological impact could be severe. In the case of the limited meltdown accident at Pennsylvania's Three Mile Island in 1979, a governor's commission report showed that one of the main health effects of the accident was on the mental health status of people in the region.

RADIOLOGICAL DISPERSAL DEVICE (RDD)

- This is a radiological threat that does not involve a nuclear blast.
- Terrorists could obtain radioactive materials to use in such a device. Radioactive materials can come from a nuclear power plant, medical or research facility, or food-processing plant.
- Radioactive materials could be dispersed by using explosives (e.g., dirty bomb) or other means, such as aerosols or sprays.
- A dirty bomb involves conventional explosives laced with radioactive material, so that the blast would contaminate an area with radioactive particles.
- In the case of a dirty bomb, the resulting blast could kill people in the immediate area and spread contamination around an area the size of several city blocks.
- Though the death toll and radiation exposure would be limited, the psychological impact could be severe. In this vein, some have dubbed the dirty bomb a "weapon of mass *disruption*."
- Radiological material can also be covertly placed in areas where it could easily expose people to radiation. This hidden source is often referred to as a "silent" source or may be called a radiation-emitting device. This method of radiation release does not involve an explosion or dispersal of radioactive materials by any other means.

IMPROVISED NUCLEAR DEVICE (IND)

- This is a small nuclear weapon (see section below) capable of producing a nuclear blast.
- The physical size of these weapons can be small enough to fit in a suitcase (i.e., suitcase bomb).
- The design and destructive nature of an improvised nuclear device is comparable to the bomb dropped on Hiroshima, Japan, at the end of World War II.

NUCLEAR WEAPON

- A nuclear weapon produces a nuclear detonation involving the joining (fusion) or splitting (fission) of atoms to produce an intense pulse or wave of heat, light, air pressure, and radiation.
- Highly processed plutonium or uranium undergoes fission in a chain reaction blast.
- The blast is designed to cause catastrophic damage to people, buildings, and the environment.
- Highly guarded materials and technical expertise are required to produce these weapons.
- The extent of damage depends on the yield (power) of the bomb. The destructive nature of these weapons can be in the order of 100 times the bomb dropped on Hiroshima.
- When a nuclear weapon explodes, a large fireball is created. Everything inside of this fireball vaporizes, including soil and water, and is carried upwards. This creates the mushroom cloud that is associated with a nuclear blast, detonation, or explosion.

- Radioactive material from the nuclear device mixes with the vaporized material in the mushroom cloud. As this vaporized radioactive material cools, it becomes condensed and forms particles, such as dust. The condensed radioactive material then falls back to the earth; this is what is known as fallout.
- Because fallout is in the form of particles, it can be carried long distances on wind currents and end up miles from the site of the explosion.
- Fallout is radioactive and can cause contamination of anything on which it lands, including food and water supplies.

WHAT WE DO NOT KNOW ABOUT NUCLEAR/RADIOLOGICAL AGENTS AS WEAPONS

- Because there is a wide range of possible scenarios, it is difficult to predict beforehand how elevated radiation exposures will be, how extensive the radioactive contamination will be, or how much effort would be involved in cleanup and recovery.
- In the case of an attack on a nuclear power plant, it is unlikely that any radioactive materials would be released to the area outside the facility, but the possibility cannot be categorically ruled out.
- In the case of a dirty bomb, the overall impact will depend on many factors, such as specific radioactive material used in the bomb and wind and weather conditions at the time of the blast.
- The impact of other types of RDDs and silent sources also depends on a variety of factors, including size of the source and how early the device or source is detected.
- The overall impact of a nuclear blast depends on its size, whether there is fallout, how populated the target area is, and how much of the potential local response infrastructure is destroyed.

ASSESSING THE RISK

- The highly purified plutonium and uranium needed to make a nuclear weapon or suitcase bomb are **difficult to acquire.** Considerable engineering skill and expertise would be required to construct a nuclear device using plutonium; devices using uranium are technically easier to construct.
- Other radiological materials, such as cesium-137 or cobalt-60, that would be suitable for use in a RDD are **moderately available** since they can be found in research, medical, and food irradiation facilities.
- Certain radioactive materials can **persist for years** or even decades in the environment. The half-life of cesium-137, for example, is about 30 years. Other radioisotopes have much shorter half-lives (e.g., iodine-131 has a half-life of about 8 days).
- Though the construction of a nuclear weapon or suitcase bomb involves advanced scientific knowledge, terrorists would only have to be **moderately skilled** to construct a dirty bomb, which simply involves wrapping conventional explosives around radioactive materials.
- A nuclear blast would be **highly lethal,** potentially killing a very large number of victims, whereas the effects of an RDD attack would almost certainly be much less severe.

TABLE 1: EFFECTS OF DIFFERENT RADIATION EMERGENCIES

	NUCLEAR POWER PLANT ATTACK	RADIOLOGICAL DISPERSAL DEVICE (RDD)
Type of Event	Radiological	Radiological
Examples of Radiation Dispersal	Possible escape of radioactive material from attack on plant	• Conventional explosives laced with radioactive material (e.g., dirty bomb) • Aerosols or sprays
Nuclear Blast	No	No
Amount of Radiation Exposure	• Less than a nuclear event • Although unlikely, radioactive materials could escape/ contaminate the area and environment	• Limited • Dirty bomb blast could spread contamination around area the size of several city blocks
Consequences	• Death toll could be limited • Plants are built to sustain extensive damage without releasing radioactive material • Psychological impact could be severe	• Limited death toll • In the case of a dirty bomb, initial explosion could kill or injure people in the immediate area • Psychological impact could be severe

RADIATION-EMITTING DEVICE (RED)	IMPROVISED NUCLEAR DEVICE (IND)	NUCLEAR WEAPON
Radiological	Nuclear	Nuclear
Hiding radioactive material in a populated area	Smaller nuclear weapon (e.g., suitcase bomb)	Nuclear weapon developed for strategic military purposes
No	• Smaller nuclear explosion of varying size • Can be as large as the bomb dropped on Hiroshima	• Highly destructive nuclear explosion • Can be in the order of 100 times the bomb dropped on Hiroshima
• Limited • Depends on the size of the source and speed of detection	• Varying • May or may not include fallout	• Large • Radioactive particles from the fallout could be carried long distances
• Depends on the size of source, how early it is detected, and other factors • Psychological impact could be severe	• Depends on the size of the blast, whether there is fallout, and population of area • Psychological impact could be severe	• Catastrophic damage to people, buildings, and the environment • Psychological impact could be severe

INSTRUCTIONS TO SHELTER-IN-PLACE AND SEAL THE ROOM DUE TO RADIATION EMERGENCIES

If you have been exposed:

- If coming from outside, remove outer layer of clothing and seal it in a plastic bag
- Shower and gently wash with soap, if possible

To shelter-in-place and seal the room:

- Find a room with as few windows and doors as possible
- Go to the *lowest* level possible
- Turn off the air conditioner, heater, and fans
- Close the fireplace damper
- Fill sinks and tubs with water
- Turn on the radio for instructions
- Keep a telephone handy
- If emergency officials instruct you to seal the room, tape plastic over windows and doors; seal with duct tape. Tape over vents and electrical outlets (and any other openings).*

* Within a few hours, the plastic and tape may need to be removed to allow fresh air to enter the room to prevent suffocation. *Follow the instructions of emergency workers and/or public health officials.*

LESSENING THE IMPACT OF EXPOSURE (to Radiological Agents, in General)

- Follow the instructions of emergency workers, if possible.
- The most important concepts to minimize exposure are time, distance, and shielding.
  - Time: Decrease the amount of time spent near the radiation source.
  - Distance: Increase your distance from the radiation source.
  - Shielding: Increase the shielding between you and the radiation source. Shielding is anything that creates a barrier between people and the radiation source.
- Stay indoors and "shelter-in-place" to reduce exposure. Being inside a building (particularly basement), inside a vehicle, or behind a wall would provide some protection.
- Close doors and windows and shut off ventilation systems using outside air.
- If outdoors, cover mouth and nose with a scarf, handkerchief, or other type of cloth to avoid inhaling radioactive dust.
- If near the site of an attack and dust or debris is on one's body or clothing, decontaminate (remove outer layer of clothing and bag it, shower without harsh scrubbing, and wash hair) before leaving to avoid spreading contamination.
- Treatment of life-threatening injuries should not be delayed in order to perform decontamination. Seek medical attention if injured by the explosion.
- Do not eat potentially contaminated foods or drink potentially contaminated water.
- Federal agencies have developed real-time models to predict how a nuclear or radiological attack would affect a given area. This information can be used to quicken response efforts and limit the number of people affected by an attack.

THE IMPACT OF RADIATION EMERGENCIES

A nuclear or radiological event could have a wide range of impacts, including immediate or long-term health effects, psychological impacts, environmental contamination, and economic consequences. The magnitudes of these impacts are highly dependent on specific circumstances of the incident.

RADIATION INJURIES

- Radiation injuries could result from the aftermath of a nuclear blast and are less likely following a radiological incident.
- Health effects may not be apparent for months or even years after exposure to radiation.
- The type and extent of injury may depend on:
  - The amount (dose) of radiation to which a person is exposed
  - The type of radiation (alpha, beta, gamma) to which a person is exposed
  - Whether a person is exposed to radiation externally (e.g., skin) versus internally (e.g., inhaled)

- If someone is contaminated with radioactive materials externally (e.g., on his or her clothing), exposure may be reduced by decontamination (e.g., removing outer layer of clothing and showering).
- Internal contamination occurs if someone ingests or inhales radioactive materials and the materials are incorporated by the body. Medications may help reduce the amount of radioactive materials in the body.
- A person may be exposed to radiation without being contaminated with radioactive materials. For example, after a nuclear detonation, penetrating radiation may expose a person to radiation (similar to receiving an X-ray) without necessarily contaminating the person with radioactive materials. More information on the distinction between exposure and contamination (internal and external) can be found at http://www.bt.cdc.gov/radiation/contamination.asp.
- If the radiation dose is large enough, victims can develop what is called acute radiation syndrome or radiation sickness. Symptoms, not all of which develop at the same time, include nausea, vomiting, diarrhea, fever, loss of appetite, skin damage (e.g., redness, itching, swelling, blisters), seizures, and coma. These symptoms are non-specific and may be indistinguishable from those of other injuries or illness. More information on acute radiation syndrome can be found at http://www.bt.cdc.gov/radiation/ars.asp.
- If the radiation dose is small, no immediate health effects will be observed. In the long-term, there may be an increased risk of developing cancer.
- In general, the higher the radiation dose the greater the severity of immediate health effects and the greater the possibility of long-term health effects.
- Children exposed to radiation may be more at risk than adults. Radiation exposure to the unborn child is of special concern because the human embryo or fetus is extremely sensitive to radiation.

TREATMENT

- After a nuclear or radiological incident, many victims would likely need to be treated for injuries associated with the explosion, such as burns, wounds, fractures, and bleeding.
- Those who have been contaminated with radioactive materials should decontaminate themselves by removing the outer layer of clothing, placing the clothing in a bag and sealing it, and taking a shower without harsh scrubbing, and wash hair.
- For victims suffering from radiation sickness, treatment would depend on the severity of the symptoms. Physicians will treat symptoms, provide supportive care, and try to prevent infections.
- There are different classes of drugs that can help treat people who have been contaminated with or exposed to radiation.

SHELTER-IN-PLACE* SUPPLY LIST

(Maintain enough for 3 days; check supplies every 6 months)

- Food
- Bottled water (1 gallon per day per person, plus water for pets)
- Change of clothing (including undergarments)
- Shoes
- First aid kit
- Paper goods and plastic utensils
- Plastic garbage bags
- Bedding
- Battery-operated radio
- Batteries
- Flashlight
- Medicines
- Toiletries
- Telephone (hard-wired phones are best)
- Emergency-contact phone list
- Extra eyeglasses or contact lenses
- Baby formula
- Pet food
- Plastic sheeting
- Duct tape

* More extensive emergency supply checklists can be found in appendices F and G (see pp. 241–244).

- Blocking agents prevent absorption of certain radioactive material in the body. **Example:** Potassium iodide
- Decorporation agents speed up elimination of certain radioactive materials from the body. **Examples:** Prussian blue; diethylenetriaminepentaacetate
- Other drugs are used to help recovery from radiation sickness. **Example:** Neupogen®

› Potassium iodide, when taken before or soon after exposure to radioactive iodine, can protect the thyroid gland from absorbing radioactive iodine and developing thyroid cancer, but this does not help against other forms of radioactivity that may come with an attack. In addition, not all attacks will involve the release of radioactive iodine.

› Prussian blue can be used to remove cesium and thallium from the body.

› Diethylenetriaminepentaacetate is a calcium or zinc salt and is typically used for medical imaging of certain organs but can also remove a number of radioactive materials from people's bodies.

› Neupogen® can be used to help the recovery of bone marrow.

› The worst cases of radiation sickness may require blood transfusions and bone marrow transplants.

› There is no vaccine or drug that can make people immune to the effects of radiation.

ADDITIONAL SOURCES OF INFORMATION ON RADIATION EMERGENCIES

› Centers for Disease Control and Prevention Hotline for the Public, 1-888-246-2675 (http://www.bt.cdc.gov/radiation/)

› Conference of Radiation Control Program Directors, 1-502-227-4543 (http://www.crcpd.org)

› Environmental Protection Agency (http://www.epa.gov/radiation/rert)

› Nuclear Regulatory Commission, 1-301-415-8200 (http://www.nrc.gov)

› Federal Emergency Management Agency, 1-202-646-4600 (http://www.fema.gov)

› Radiation Emergency Assistance Center/Training Site, 1-865-576-3131 (http://www.orau.gov/reacts)

› U.S. National Response Team (http://www.nrt.org)

› U.S. Department of Energy, 1-800-dial-DOE (http://www.energy.gov)

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