



RADIATION



PROTECTION



and the NRC





## *Radiation is all around us.*

It is naturally present in our environment and has been since before the birth of this planet. Radiation occurs in nature, but it can also be produced artificially, as in medical x-rays and microwaves for cooking. Radiation can be either beneficial or harmful, depending on its use and control. Therefore, regulation of certain radioactive sources is necessary so that people are protected from unnecessary or excessive exposures.



*Radiation exists naturally everywhere on earth.*

## WHAT IS RADIATION?

Radiation is energy given off by matter in the form of rays or high-speed particles. There are many forms of radiation that are familiar to us. For example, we use light, heat, and microwaves every day. Doctors use x-rays to see inside our bodies. Radio and television waves bring us our favorite shows. All of these are forms of radiation.

Radiation is either ionizing or non-ionizing, depending on how it affects matter. Non-ionizing radiation includes visible light, heat, radar, microwaves, and radio waves. It deposits energy in materials it passes through. Conversely, ionizing radiation, such as x-rays and cosmic rays, is more energetic than non-ionizing radiation. When ionizing radiation passes through material, enough energy is deposited to break molecular bonds and create charged particles. These charged particles can damage plant, animal, and human cells, but they can also be used beneficially. For example, we use ionizing radiation to treat cancer, sterilize medical equipment, and in smoke detectors. The U.S. Nuclear Regulatory Commission is the Federal agency that regulates nuclear materials that produce ionizing radiation.



*Smoke detectors with a small amount of radioactive material.*

## WHERE DOES RADIATION COME FROM?

Although we receive ionizing radiation from both natural and artificial sources, most people are not aware of all sources of radiation in their environment.

*The NRC is the Federal agency responsible for regulating the safe uses of radioactive materials for civilian purposes in the United States to ensure the protection of public health and safety and the environment.*



NRC Headquarters

The sun and stars send a constant stream of cosmic radiation to Earth, much like a steady drizzle of rain. Differences in elevation, atmospheric conditions, and the Earth's magnetic field can change the amount of cosmic radiation that we receive.

The Earth itself is also a source of terrestrial radiation. Radioactive materials uranium, radium and thorium exist naturally in soil and rock. Essentially all air contains radon, water contains small amounts of dissolved uranium and thorium, and all organic matter, both plant and animal, contains radioactive carbon and potassium. All people have internal radiation, mainly from radioactive potassium-40 and carbon-14, inside their bodies from birth. In addition to natural sources, there are artificial or man-made sources of radiation. These include medical sources (diagnostic x-rays and nuclear medicine procedures), consumer products (televvisions, smoke detectors, luminous watches, and some ceramics), and industrial sources (nuclear power plants and industrial radiography).



*Nuclear medicine*

## WHAT TYPES OF RADIATION ARE THERE?

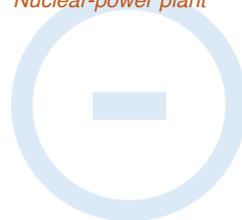
As we mentioned before, radiation can be ionizing or non-ionizing. We are typically more concerned about ionizing radiation because even though it has beneficial uses, it is also potentially harmful if not used correctly. Because of this potential hazard, the NRC strictly regulates commercial and institutional uses of nuclear material, including nuclear power plants.



*Nuclear-power plant*

There are five major types of ionizing radiation:

- **alpha particles**
- **beta particles**
- **gamma rays**
- **x-rays**
- **neutrons**



**Alpha particles** are charged particles with very little penetrating power. They can be blocked by a sheet of paper, skin or a few inches of air. Alpha particles do not usually make anything radioactive.

Materials that emit alpha particles are potentially dangerous when inhaled or swallowed, not because of external exposure. Alpha particles are emitted from naturally-occurring materials such as uranium, thorium, and radium and from man-made elements such as plutonium and americium. Very small amounts of alpha emitters are used in items such as smoke detectors.

**Beta particles**, which are similar to electrons, are lighter and more penetrating than alpha particles, can travel a few feet in the air, and can penetrate the skin. Like alpha particles, they do not usually make things radioactive. A thin sheet of metal or plastic or a block of wood can stop a beta particle. Beta emitters, such as strontium-90, are used in medical applications such as treating eye disease.

**Gamma rays** and **x-rays** consist of high energy waves that can travel great distances at the speed of light and are very penetrating. In general, neither x-rays nor gamma rays have the ability to make anything radioactive. Several feet of concrete or a few inches of more dense material, such as lead, are needed to block these types of radiation. Because of their penetration powers, gamma rays, such as from cobalt-60, are often used in medical applications to treat cancer and to sterilize medical instruments. X-rays are typically used to provide images of stationary parts of the body such as teeth and bones and are also used in industry to find defects in welds.

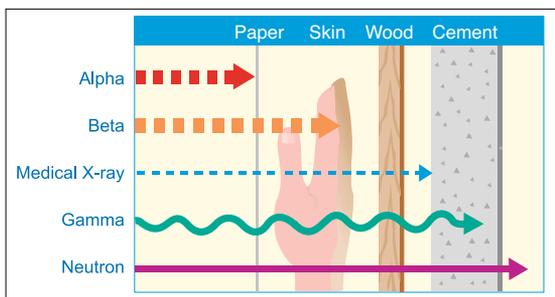


*X-rays penetration.*

**Neutrons** are nuclear particles that are also very penetrating. Neutrons are the only one of the five types discussed here that can make objects radioactive. This process, called neutron activation, is used to produce many of the radioactive sources used in commercial, academic, and medical applications. Neutrons can travel great distances in the air and require very thick hydrogen-containing material (such as concrete or water) to stop them. Neutron radiation occurs primarily inside a nuclear reactor where many feet of water provide effective shielding. Neutrons are also used in medicine research, and oil exploration.



*Nuclear power plant reactor core.*



Penetrating Power of Radiation

## HOW IS RADIATION MEASURED?

Whether it emits alpha or beta particles, gamma rays or neutrons, a quantity of radioactive material is expressed in terms of its **radioactivity**, or simply its activity, and is measured in curies. Activity represents how many atoms in the material decay in a given time period.

The activity of a radioactive material decreases with time. The time it takes for the activity of a radioactive material to decrease by half is called the radioactive half-life. After one half-life, the remaining activity is one half of the original activity. After two half-lives, the remaining activity is one fourth; after three half-lives, one eighth; and so on. Some radioactive materials, such as iodine-131, have short half-lives measured in days. Others, such as uranium-238, have half-lives measured in billions of years.



Geiger counter.

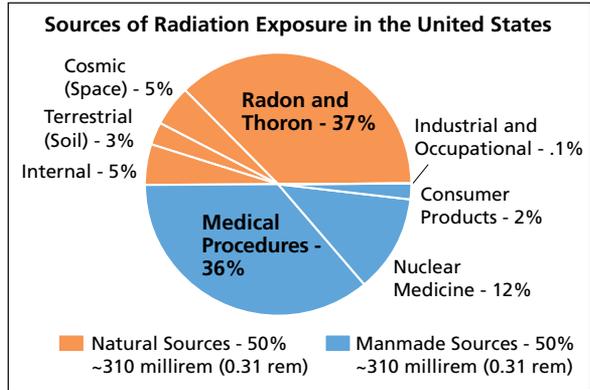
## WHAT HAPPENS WHEN LIVING THINGS ARE EXPOSED TO RADIATION?

We tend to think of radiation exposure in terms of its effect on living cells. For low levels of radiation exposure, the effects are so small they may not be detected, because a body can repair damage caused by radiation. The health effects of radiation on living cells may result in three outcomes: (1) injured or damaged cells repair themselves, resulting in no net damage; (2) cells die, much like millions of body cells do every day, being replaced through normal biological processes; or (3) cells incorrectly repair themselves resulting in a physical change. The exact effect depends on the specific type and intensity of the radiation exposure.

The amount of energy deposited in material by ionizing radiation is called dose. Biological doses are measured in units called rems.

Where curies tell us the radioactivity of a substance, rems tell us the amount of energy that radiation has deposited in an area of living tissue. The likelihood of effects caused by radiation is related to the dose of radiation received, regardless of whether the radiation is of natural or artificial origin.

On average, Americans receive a dose of about 0.31 rems (310 millirems) each year from natural or background radiation. Most of this exposure comes from radon in the air with lesser amounts from cosmic rays and the



Earth itself. We also receive about 0.31 rems (310 mrem) yearly from man-made sources of radiation, including medical, commercial, and industrial sources. Nuclear medical procedures provide the largest amount of human exposure to man-made radiation. For example, a chest x-ray typically gives a dose of about 0.01 rems (10 mrem) and a CT (full body) scan gives a dose of about 1 rem (1,000 mrem). The average dose is regularly re-evaluated.

*A yearly dose of 0.62 rems (620 millirems) from all radiation sources has not been shown to cause humans any harm.*

Because radiation from nuclear material is strictly regulated, large doses (~50 rems) of radiation to humans seldom occur. However, high radiation doses, particularly over a short period of time, kill many cells and can damage tissues and organs. Although radiation affects different people in different ways, it is believed that humans exposed to about 500 rems of radiation all at once would likely die without medical treatment. A single dose of 100 rems to a human may cause nausea or skin reddening, but recovery is likely. About 25 rems of radiation can cause temporary sterility in men. If these doses are spread out over time, instead of delivered all at once, their effects tend to be less severe.

## HOW CAN RADIATION EXPOSURE BE REDUCED?

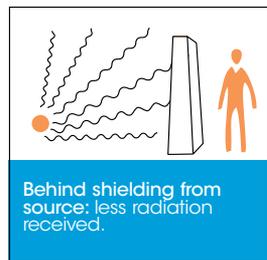
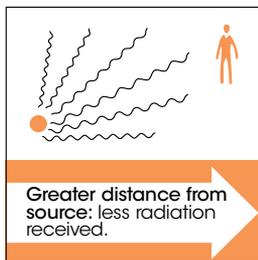
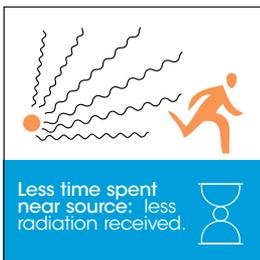
Although exposure to ionizing radiation carries a risk, it is impossible to completely avoid exposure. We can, however, minimize

exposure from discrete sources of radiation in three basic ways. They work much the same way as protection against overexposure to the sun.

**1 Time:** The concept of time works in two ways. Limiting or minimizing the amount of exposure time will reduce the dose from the radiation source. Also, allowing radioactive material as much time as possible to decay before exposure will minimize radiation exposure when that material needs to be handled.

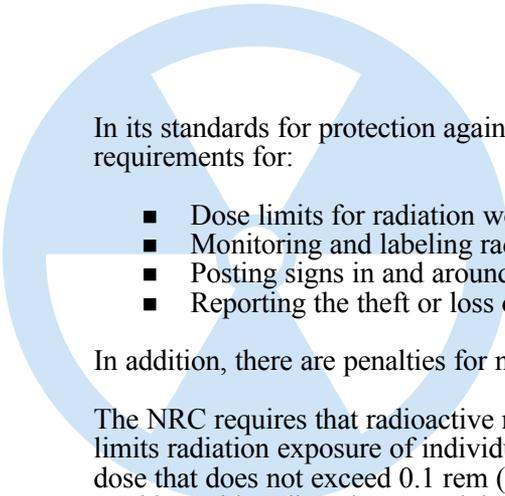
**2 Distance:** Increasing the distance from the radiation source will sharply decrease exposure. The intensity of radiation decreases the further you are from the source in the same way that the heat from a fire is less intense the further away you are from it.

**3 Shielding:** Inserting a solid material or shield between yourself and a radiation source will greatly reduce the radiation dose. Barriers of lead, concrete or water provide protection from radiation from gamma rays and neutrons. This is why certain radioactive materials are stored under water or in concrete or lead-lined rooms, and why dentists place a lead blanket on patients receiving x-rays of their teeth.



## HOW DOES NRC HELP PROTECT THE PUBLIC FROM RADIATION EXPOSURE?

**R**adiation and its risks command considerable public attention. However, a system of radiation protection has been developed over many decades as the effects of radiation have become better understood. Specifically, the NRC ensures that users of radioactive materials keep radiation exposures within its dose limits and as low as reasonably achievable. Users must obtain a license from the NRC and be inspected by the NRC to make sure they are following regulations and using radioactive materials safely.



In its standards for protection against radiation, the NRC has requirements for:

- Dose limits for radiation workers and members of the public
- Monitoring and labeling radioactive materials
- Posting signs in and around radiation areas
- Reporting the theft or loss of radioactive material

In addition, there are penalties for not following NRC regulations.

The NRC requires that radioactive materials be used in a way that limits radiation exposure of individual members of the public to a dose that does not exceed 0.1 rem (100 mrem) in a year. Adults working with radioactive material must be protected so as not to receive more than 5 rems (5,000 mrem) per year. Because workers are exposed to various radiation sources, they are carefully monitored with the use of small instruments called dosimeters.

If certain conditions are met, the NRC may enter into an agreement with the governor of a state to turn over authority for regulating radioactive materials to that state. States that meet these conditions and agree to regulate materials using the same standards as the NRC are called Agreement States. Typically, Agreement States regulate all sources of radiation in the state except nuclear power plants, large quantities of certain nuclear material, and any high-level radioactive waste stored in the state. Currently, 34 states have such agreements with the NRC.

For more information on radiation protection, please visit our website at: [www.nrc.gov](http://www.nrc.gov) and click on the second blue box, Radiation Protection, on the left-hand side of the screen.



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