

	<h2 style="margin: 0;">Radiation and Human Health</h2>	Effective:	December 1, 2005
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### Radiation and Human Health

#### 1. Purpose

Radiation is part of our everyday lives. We are all exposed to radiation from the sun and in the atmosphere; naturally occurring radioactive materials are present in the earth, the houses we live in, and the foods we eat. Radioactive gases are mixed in the air we breathe; and even our own bodies contain naturally occurring elements that are radioactive. This inescapable radiation exposure is called "natural background" and it varies from place to place.

In addition, we create and use sources of radiation for medical uses in the diagnosis and treatment of injury and disease.

#### 2. Instruction

##### What is it?

The word radiation is general and includes light, radio waves, and electric fields. These are examples of non-ionizing radiations, whose energies are lower than ionizing radiation. They do not affect matter in the same way.

Ionizing radiation changes the physical state of atoms it strikes causing them to become electrically charged or "ionized".

All matter is made up of atoms. The basic parts of atoms are neutrons, protons, and electrons. Neutrons and protons form the nucleus of the atom and electrons surround (orbit) the nucleus. An atom of a particular element has a unique number of protons in its nucleus. Certain combinations of protons and neutrons are stable (not radioactive). When an atom has an unstable combination of neutrons and protons, the atom will decay (emit radiation). These unstable atoms are called "radioisotopes."

##### Main Types of Ionizing Radiations:

- **Alpha Particles** consist of heavy, positively charged particles emitted by atoms of heavy elements such as naturally occurring uranium and radium and some human-made sources. Alpha particles are completely absorbed by the outer dead layer of skin and are therefore not a hazard outside the body. If alpha particles are taken into the body by inhalation or with food or water, they can directly expose internal tissues and can be a hazard.
- **Beta Particles** (positively or negatively charged electrons) are emitted from the nucleus during decay. Beta particles are more penetrating than alpha particles and

can sometimes penetrate the skin, but like alpha particles, they are generally more hazardous when inhaled or ingested. In air, beta particles may be stopped by plastic or wood. Carbon 14 ( $^{14}\text{C}$ ), an example of a radioisotope that emits beta particles, is naturally produced in the atmosphere.

- **Gamma and X-rays** are forms of electromagnetic radiations because they have both electric and magnetic properties. Gamma rays, or photons, come from the nucleus when materials decay. X-rays are a result of electron removal or rearrangement in atoms. Gamma and x-ray radiations are used frequently in medicine because they can easily penetrate the human body.
- **Neutrons** are heavy, uncharged particles that cause the atoms that they strike to become ionized.

### **From Radiation Exposure to Dose:**

Damage from radiation depends on several factors such as whether the exposure was from internal or external sources. The unit for measuring absorbed energy as radiation exposure to the human body is the rem (Roentgen Equivalent Man).

**External Exposure** comes from a source outside the body, such as a medical x-ray. To do harm, the radiation must have enough energy to penetrate the body. If it does, three factors affect the radiation dose that the individual will receive:

- The amount of **time** the individual was exposed
- The **distance** from the source of radiation
- The amount of **shielding** between the individual and the source of radiation.

The longer a person is exposed to a source of radiation, the higher the radiation dose. The relationship between distance and exposure is not as simple because the intensity of radiation falls off very quickly. For example, if a source produces a radiation dose rate to an individual of 1 rem per hour at a distance of 1 foot, twice the distance (2 feet), the dose rate will be one-fourth of 1 rem per hour or 0.25 rem per hour. At three feet, the rate will be one-ninth of 1 rem per hour or 0.11 rem per hour.

Any material between the source of radiation and the person exposed is considered shielding. As the thickness of a shielding material increases, the absorption of radioactive emissions also increases.

The following shielding guidelines can be used:

- Alpha particles ( $\alpha$ ) stopped by paper
- Beta particles ( $\beta$ ) stopped by wood or Plexiglas
- Gamma ( $\gamma$ ) and X-rays (X) stopped by lead or concrete
- Neutrons ( $n$ ) absorbed by hydrogen-rich materials

**Internal Exposure** can occur when a radioisotope enters the body by inhalation, ingestion, or through an open wound. If this happens, any kind of radiation can directly harm living cells. The damage the radiation produces depends on the following factors:

- The amount of radioactive material deposited into the body
- The type of radiation emitted
- The physical characteristics of the element;
- The half-life of the radioisotope (how fast it decays away)
- The length of time in the body.

**Can Radiation be Harmful?**

An average of 1,800 people in every 10,000 die from cancer each year. If all 10,000 people received 1 rem each as a single exposure, we would expect 1 additional person to die of cancer. However, it is not possible to tell which of the 1,801 fatal cancers was caused by the radiation.

Genetic disorders in offspring are estimated as follows: Assume a 1 rem dose to the sperm of 1 million fathers or the eggs of 1 million mothers. This dose may produce between 5 and 75 serious genetic illnesses per 1 million live births. Add this to the 90,000 genetic illnesses expected among any 1 million live births. Thus, a 1 rem dose plus the normal incidence rate would result in 90,005 - 90,075 genetic illnesses for each 1 million live births.

**Radiation Dose Perspective**

1 millirem dose:	One one-thousandth of a rem.
2.5 millirem dose:	Cosmic radiation dose to a person on a one-way flight from New York to Los Angeles.
10 millirem dose	One chest x-ray using modern equipment.
25 millirem dose:	Yearly exposure limit set by the Environmental Protection Agency for people who live near nuclear power plants.
60-80 millirem dose:	Average yearly radiation dose from cosmic radiation to people who live in the Rocky Mountain States.
100 millirem dose:	Yearly limit from all sources of human-made radiation (non-radiation worker) set by the NRC.
160 millirem dose:	Yearly dose to the average flight crew members from cosmic radiation.
300 millirem dose:	Average yearly dose to people in the U.S. (background radiation).
5 rem dose:	Yearly limit for radiation workers set by the NRC (external and internal).
25 rem dose:	EPA guideline for voluntary maximum radiation dose to emergency workers for non-lifesaving work during a reactor emergency. Assumed to be a once-in-a-lifetime event.
75 rem dose:	EPA guideline for maximum radiation dose to emergency workers volunteering for lifesaving work.

### **Radiation Dose Effects - Low Exposure**

Biological effects of radiation exposure can be classified as either stochastic (random) or deterministic. A stochastic effect is one in which the probability of the effect, rather than its severity, increases with radiation dose. Radiation-induced cancer and genetic effects are stochastic; the probability of occurrence is substantially higher after an exposure to 100 rem than for 1 rem, but there will be no difference in the severity of the disease if it occurs.

Deterministic effects occur when the radiation exposure is very high and the predominant biological effect is cell killing that results in degenerative changes in the exposed tissue. Deterministic effects are discussed below and are not likely to occur from diagnostic procedures or routine occupational exposure.

### **Radiation Dose Effect - High Exposure**

This information is based on known cases of high exposure delivered quickly over the whole body.

50-200 rem:	At the lower end of this range, the symptoms of acute radiation syndrome: anorexia, nausea, vomiting, and diarrhea can be delayed as much as a few weeks. A slight decrease in blood cell count can be noted. Survival with or without treatment is almost certain. At the upper end of this range, symptoms are more severe and early symptoms of bone marrow damage are noted. Survival without treatment is probable; and almost certain if treatment is given.
200-500 rem:	Anorexia, nausea, vomiting, and diarrhea occur sooner and are more severe. Moderate to severe bone marrow damage and slight intestinal damage occurs. Without treatment, death is likely; survival with treatment is possible.
500-600 rem:	Severe anorexia, nausea, vomiting, and diarrhea occur. Moderate to severe bone marrow and intestinal damage and hypotension. Death is likely.

- Reference: "The Essential Physics of Medical Imaging", Bushberg, et.al., Williams & Wilkins 1994.

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