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United States
Environmental Protection Agency

Office of Air and Radiation
Office of Radiation and Indoor Air

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Ionizing Radiation
Fact Book

Table of Contents

General Description

Ionizing radiation is energy in the form of waves or particles that has enough force to remove electrons from atoms. In this document, we will refer to it simply as radiation. One source of radiation is the nuclei of unstable atoms. As these radioactive atoms (also referred to as radionuclides or radioisotopes) seek to become more stable, their nuclei eject or emit particles and high-energy waves. This process is known as radioactive decay.

Some radionuclides, such as radium, uranium, and thorium, have existed since the formation of the earth. The radioactive gas radon is one type of radioactive material produced as these naturally-occurring radioisotopes decay. Human activities, such as the splitting of atoms in a nuclear reactor, can also create radionuclides. Regardless of how they are created, all radionuclides release radiation.

The major types of radiation emitted during radioactive decay are alpha particles, beta particles, and gamma rays. Radiation can come from natural sources or man-made radionuclides. Man-made x-rays, another type of radiation, are produced outside of the nucleus. Most x-ray exposure that people receive is technologically produced.

Alpha Particles

Alpha particles are energetic, positively charge particles consisting of two protons and two neutrons. Alpha particles are commonly emitted in the radioactive decay of the heaviest radioactive elements such as uranium-238, radium-226, and polonium-210. Even though they are highly energetic, the high mass of alpha particles means they move slowly through the air.

The health effects of alpha particles depend heavily upon how exposure takes place. External exposure (external to the body) is of far less concern than internal exposure, because alpha particles lack the energy to penetrate the outer dead layer of skin. Internally alpha particle can be very harmful. If alpha emitters are inhaled, ingested (swallowed), or absorbed into the blood stream, sensitive living tissue can be exposed to alpha radiation.

Beta Particles

Beta particles are fast moving electrons emitted from the nucleus during radioactive decay. Humans are exposed to beta particles from man-made and natural radiation sources, such as tritium, carbon-14, and strontium-90.

Beta particles are more penetrating than alpha particles but are less damaging over equally traveled distances. They travel considerable distances in air but can be reduced or stopped by a layer of clothing or by a few millimeters of a substance, such as aluminum. Some beta particles are capable of penetrating the skin and causing radiation damage, such as skin burns. However, as with alpha-emitters, beta-emitters are most hazardous when they are inhaled or ingested.

… alpha & beta-emitters are more hazardous when they are ingested or inhaled…"

Gamma Rays

Like visible light and x-rays, gamma rays are weightless packets of energy called photons. Gamma rays often accompany the emission of alpha or beta particles from a nucleus. They have neither a charge nor a mass and are very penetrating. Several feet of concrete or a few inches of lead may be required to stop gamma rays.

One source of gamma rays in the environment is naturally-occurring potassium-40. Man-made sources include cobalt-60 and cesium-137. Gamma rays are a radiation hazard for the entire body. While gamma rays can easily pass completely through the human body, a fraction will always be absorbed by tissue.

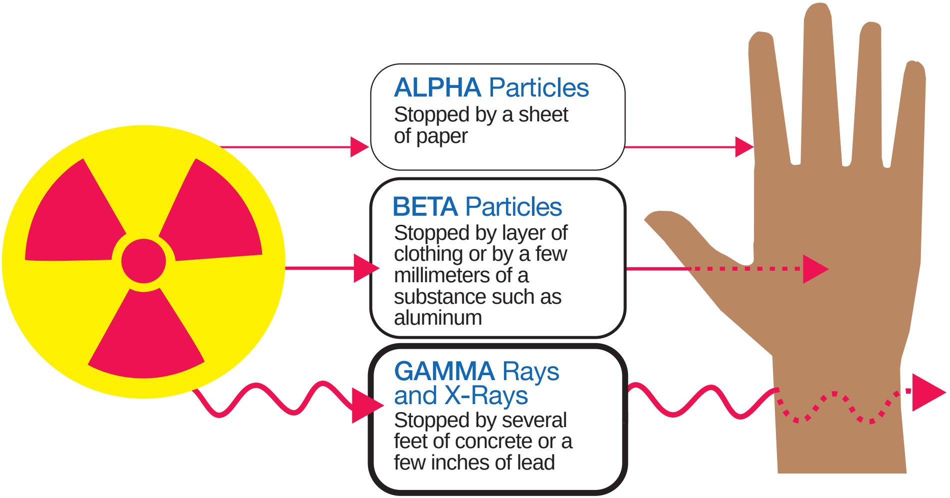
...hazard for the entire body...

X-rays

X-rays are high-energy photons produced by the interaction of charged particles with matter. X-rays and gamma rays have essentially the same properties but differ in origin. X-rays are either produced from a change in the electron structure of the atom or are machine produced. They are emitted from processes outside the nucleus, while gamma rays originate inside the nucleus. They also are generally lower in energy and therefore less penetrating than gamma rays. A few millimeters of lead can stop x-rays.

Literally thousands of x-ray machines are used daily in medicine and industry for examinations, inspections, and process controls. Because of their many uses, x-rays are the single largest source of man-made radiation exposure.

Penetrating Powers of Alpha Particles, Beta Particles, Gamma and X-Rays



Sources of Radiation

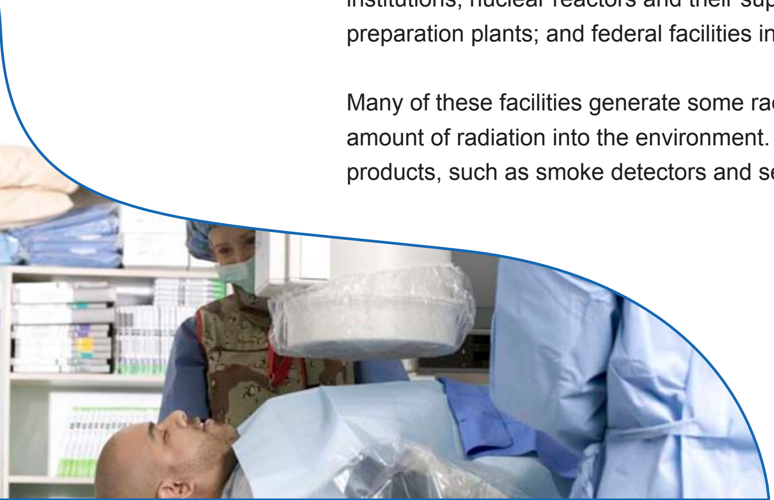
Natural Radiation

Humans are primarily exposed to natural radiation from the sun, cosmic rays, and naturally-occurring radioactive elements found in the earth's crust. Cosmic rays from space include energetic protons, electrons, gamma rays, and x-rays. Radon gas, which emanates from the ground, comes from the decay of naturally-occurring radium and is a major source of radiation exposure. The primary radioactive elements found in the earth's crust are uranium, thorium, and potassium, and their radioactive decay products. These elements emit alpha particles, beta particles, and gamma rays.

Manmade Radiation

Man-made radiation is radiation produced in devices, such as x-ray machines, and artificially produced radioisotopes made in a reactor or accelerator. This type of radiation is used in both medicine and industry. Main users of man-made radiation include: medical facilities, such as hospitals and pharmaceutical facilities; research and teaching institutions; nuclear reactors and their supporting facilities, such as uranium mills and fuel preparation plants; and federal facilities involved in nuclear weapons production.

Many of these facilities generate some radioactive waste, and some release a limited amount of radiation into the environment. Radioactive materials are used in consumer products, such as smoke detectors and self-illuminating exit signs.



Health Effects from Exposure to Ionizing Radiation

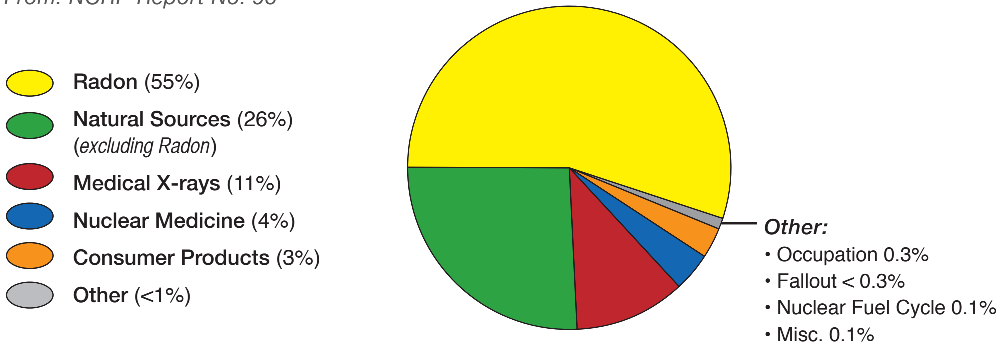
Radiation Exposure

Any release of radioactive material is a potential source of radiation exposure to the population. In addition to exposure from external sources, radiation exposure can occur internally from ingesting, inhaling, injecting, or absorbing radioactive materials. Both external and internal sources may irradiate the whole body or a portion of the body.

The amount of radiation exposure is expressed in a unit called millirem (mrem). In the United States, the average person is exposed to an effective dose equivalent of approximatly 360 mrem (whole-body exposure) per year from all sources (NCRP Report No. 93).

Sources of Radiation Exposure

From: NCRP Report No. 93



Results of Exposure

Radiation affects people by depositing energy in body tissue, which can cause cell damage or cell death. In some cases there may be no noticeable effect. In other cases, the cell may survive but become abnormal, either temporarily or permanently. Additionally, an abnormal cell may become malignant. Both large and small doses of radiation can cause cellular damage. The extent of the damage depends upon the total amount of energy absorbed, the time period and dose rate of the exposure, and the particular organs exposed.

By damaging the genetic material (DNA) contained in the body's cells, radiation can cause cancer. Damage to genetic material in reproductive cells can cause genetic mutations that can be passed on to future generations. In rare occurrences where there is a large amount of radiation exposure, sickness or even death can occur in a limited amount of hours or days.

Chronic Exposure

Chronic exposure is continuous or intermittent exposure to low doses of radiation over a long period of time. With chronic exposure, there is a delay between the exposure and the observed health effect. These effects can include cancer and other health outcomes such as benign tumors, cataracts, and potentially harmful genetic effects.

Acute Exposure

Acute exposure is exposure to a large, single dose of radiation, or a series of moderate doses received during a short period of time. Large acute doses can result from accidental or emergency exposures or from specific medical procedures (radiation therapy). For approved medical exposures, the benefit of the procedure may outweigh the risk from exposure.

In most cases, a large acute exposure to radiation causes both immediate and delayed effects. Delayed biological effects can include cataracts, temporary or permanent sterility, cancer, and harmful genetic effects. For humans and other mammals, acute exposure to the whole body, if large enough, can cause rapid development of radiation sickness, evidenced by gastrointestinal disorders, bacterial infections, hemorrhaging, anemia, loss of body fluids, and electrolyte imbalance. Extremely high dose of acute radiation exposure can result in death within a few hours, days, or weeks.

Risks of Health Effects

All people receive chronic exposure to background levels of radiation present in the environment. Many people also receive additional chronic exposures and relatively small acute exposures. For populations receiving such exposures, the primary concern is that radiation could increase the risk of cancer or harmful genetic effects.

The probability of a radiation-induced cancer or harmful genetic effects is related to the total amount of radiation accumulated by an individual. Based on current scientific evidence, any exposure to radiation can be harmful (e.g., can increase the risk of cancer); however, at very low exposures, the estimated increases in risk are very small. For this reason, cancer rates in populations receiving very low doses of excess radiation (doses of radiation above background) may be similar to the rates for average populations.

Evidence of injury from low or moderate doses of radiation may not show up for months or even years. For example, the minimum time period between the radiation exposure and the appearance of leukemia (latency period) is 2 years. For solid tumors, the latency period is more than 5 years. The types of effects and their probability of occurrence can depend on whether the exposure was chronic or acute. It should be noted that all of the long-term health effects associated with exposure to radiation can also be caused by other factors.

...may not show up for months or even years.

Estimating Health Risk

The most complete data available to scientists are on the survivors of the atomic bomb explosions in Japan, on radiation industry workers, and on people receiving large doses of medical radiation. These data demonstrate a higher incidence of cancer among exposed individuals and a greater probability of cancer as the level of exposure increases. In the absence of more direct information, the data also are used to estimate what the effects might be at lower exposures. Where questions arise, scientists try to come to conclusions based on information obtained from laboratory experiments, but these determinations are acknowledged to be uncertain. For radon, scientists largely depend on data collected on underground miners. Professionals in the radiation protection field prudently assume that the chance of a fatal cancer from radiation exposure increases in proportion to the magnitude of the exposure. In other words, it is assumed that no radiation exposure is completely risk free.

... it is assumed that no radiation exposure is completely risk free.

Suggested Reading

For introductory radiation information, please reference the following: **Radiation: Risks and Realities** (Document No. EPA-402-K-07-006). U.S. Environmental Protection Agency, 2007.

The following books and websites are possible sources for more in-depth information on the health effects of radiation exposure.

- Cember, H. ***Introduction to Health Physics. 3rd ed.,*** McGraw-Hill, 1996.
- ***"Conference of Radiation Control Program Directors, Inc."*** 2007. Conference of Radiation Control Program Directors. http://www.crcpd.org/
- ***Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2"*** The National Academies Press, Washington, D.C., 2006.
- ***"Health Physics Society."*** 2006. Health Physics Society. http://www.hps.org/
- ***Ionizing Radiation Exposure of the Population of the United States*** (NCRP Report No. 93): National Council on Radiation Protection and Measurements,1987.
- Martin, A. and Harbison, S.A., ***An Introduction to Radiation Protection. 3rd ed.,*** London: Chapman and Hall, 1987.
- ***"Radiation Protection."*** 2006. U.S. Environmental Protection Agency. http://www.epa.gov/radiation/
- Shapiro, J. ***Radiation Protection. 4th ed.,*** Harvard University Press, 2002.
- Wiley & Sons, John. ***Radiation, and Radiation Protection. 2nd ed.***, 1995.

For additional radiation information, please visit our website: **www.epa.gov/radiation**