pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

RADIATION AND RADIOACTIVITY

Introduction

All matter is made up of atoms. Most atoms are structurally stable, but the nuclear structures of some atoms change. These atoms are considered unstable or "radioactive." Unstable, radioactive atoms are referred to as radionuclides. All radionuclides seek stability, and the nuclear structure of an atom will change through a process called decay. When radioactive materials decay, atoms emit radiation and change to other atoms, called daughters. Daughter atoms may, or may not, be radioactive. Eventually, all radionuclides stop emitting radiation. Their nuclear structure stops changing, and they become stable. Radiation has been studied extensively since its discovery over a century ago and is now well understood by scientists and engineers. Instruments, devices, and procedures to detect and control radiation have been developed that provide great benefits to society (e.g., medical X-rays).

The earth, and its inhabitants, are constantly exposed to radiation emitted by the sun, the stars, and other cosmic sources, as well as from radioactive materials found naturally in the crust of the earth. Exposure to radiation is inevitable because of radioactive materials found in water, air, and even within the human body. Radiation is invisible to the human eye, but it exists in the forms of particles or electromagnetic waves. Small bundles of electromagnetic energy are called photons.

Types of Radiation

There are three basic types of ionizing radiation: alpha, beta, and gamma.

Alpha Radiation (α) is a particle that contains two protons and two neutrons, which is released from an unstable nucleus. Alpha particles can travel only a few inches in air because of their large mass and electric charge. In air, they lose energy very rapidly. A sheet of paper or outer layer of skin can block alpha particles. Alpha emitters are harmful only if taken into the body through eating, drinking, or breathing. Alpha radiation is emitted by uranium, thorium, radium, and radon that occur naturally, as well as by some non-natural elements such as plutonium.

Beta Radiation (β) is a particle, but much smaller than an alpha particle. Beta radiation consists of energetic electrons (β-) or positrons (β+). Being small and light they can travel as far as 12 to 15 feet in air. Beta particles can penetrate skin, so in some cases people should be shielded from them. Most beta particles can be stopped by shielding provided by glass, wood, plastic, or metal. Radionuclides such as strontium-90, sulfur-35, hydrogen-3 (tritium), and carbon-14 emit only beta radiation.

Gamma Radiation (γ) or **X-rays** are an electromagnetic type of radiation composed of photons, which travel in a wave-like mode similar to microwaves or radio waves. Gamma and X-rays have no charge or mass, and unlike alpha or beta particles, can travel farther. Since they can penetrate matter, they are potentially harmful to the human body. Lead, concrete, or water is typically used to shield people from gamma radiation. Radionuclides like cobalt-60, cesium-137, and iodine-131 emit gamma radiation.

Many radionuclides emit more than one kind of radiation. For example, gamma-emitting radionuclides noted above also emit beta radiation. Certain alpha-emitting radionuclides of uranium, thorium, and their decay products also emit gamma radiation.

Radiation Detection and Sources

Although radiation is invisible, it can be easily detected, measured, and controlled. It is detected and measured by devices or instruments called Geiger counters, ion chambers, dosimeters, or radiation monitors.

As noted above, everything on earth is continually exposed to radiation; energy is deposited into living organisms from that exposure. This deposited energy is called a "radiation dose." The most common and oldest unit used in the United States for measuring radiation dose is called a rem (roentgen equivalent man). Usually, the human exposure to radiation involves smaller doses; therefore, a smaller unit called a millirem (mrem) is generally used. One millirem is equal to one one-thousandth of a rem; or 1,000 millirem equals one rem. The modern unit of dose is called the sievert (Sv). One Sv equals 100 rem.

An average American receives a dose of about 620 millirem of radiation per year from a variety of sources according to the National Council on Radiation Protection & Measurements (NCRP). About 50 percent of the radiation that humans receive comes from natural sources such as radon; cosmic radiation from the sun and outer space; radioactive materials in the soil; rocks; building materials like stone, brick, and plaster; and our bodies. All humans have small amounts of radioactive elements in their bodies. The other 50 percent of radiation sources are human-made and include various diagnostic X-rays and nuclear medicine tests and procedures.

Radiation from human-made sources is no different than radiation from natural sources. The effect of radiation upon humans does not depend upon the source.

Scientists have learned a great deal about radiation since its discovery. The biological effects of radiation on animal and plant life have also been studied thoroughly by conducting numerous experiments during the last century. Many human groups exposed to radiation by accident, warfare, and for medical purposes have been studied thoroughly for ill effects. The research has shown that quickly delivered radiation doses above 100 rem (100,000 mrem) can be very harmful to humans; however, at low doses, i.e., those below 5 rem (5,000 mrem), scientists have not found conclusive evidence of any harmful effects. Nonetheless, most international and national radiation protection organizations have concluded there is a possibility for harm in the low-dose range. The dose limits established by the U.S. Nuclear Regulatory Commission for occupational radiation workers is 5,000 mrem per year and 100 mrem per year for the public.

Radiation Benefits

Radiation sources are widely utilized in such diverse fields as medicine, manufacturing, construction, agriculture, biotechnology, genetics, metallurgy, space exploration, and scientific research. Radiation provides many benefits for society, such as:

1. Radiation is used daily in hospitals and clinics to perform diagnostic imaging procedures. The most commonly used forms of radiation are from X-ray machines in dental clinics and a more sophisticated X-ray machine called a computed tomography (CT) scanner. Procedures that use radiation are necessary for accurate diagnosis of disease and injury. They provide important information about human health to personal care physicians and help ensure that the patient receives appropriate care. Benefits from the medical procedure greatly outweigh any potential small risk of harm from the amount of radiation used. In nuclear medicine procedures, a very small amount of radioactive material is injected, swallowed, or inhaled by the patient. Then, a special camera is used to detect gamma radiation emitted by the radioactive material in the patient's body and form a picture of the organs and their function on a computer monitor.
2. In radiation therapy, much higher doses are given with the intent of destroying cancer tissues. Small sources may be placed very near to, or in direct contact with, cancer tissues (brachytherapy) and only left in place for defined periods of time. Therapy is also performed with internal radioactive sources, like those used in diagnostic nuclear medicine. These sources are labeled to special molecules that are designed to be taken up preferentially by cancer cells and less by other organs and tissues, and thus lead to a positive outcome without compromising the health of the patient. Most commonly, external high energy X-ray techniques are used to focus the radiation dose in the area of interest and give lower doses to normal tissues.
3. In industry, radioactive gauges are unparalleled in their precision, reliability, convenience, and value. They are used to check densities and control fill-levels in industries manufacturing food and beverages; measure thickness of sheet materials like steel, aluminum, plastic, paper, and textile; measure density of road surfaces and concrete; explore oil, gas, and minerals; and detect air, water, and soil pollution.
4. Radionuclides are also used in consumer products such as smoke detectors and self-luminescent watches. The manufacture of products such as automobiles, tires, gasoline, non-stick pans, and appliances, and the sterilization of cosmetics, hair products, bandages, gauze pads, disposable diapers, and contact lens solutions use radiation sources. They are also used to prevent accumulation of static electricity and the consequent sticking of paper in printing presses, paper-making machinery, and photocopiers.
5. Radiographic inspection provides a non-destructive method to check weld integrity of large structures such as bridges, buildings, aircraft frames, ships, automobiles, metal tankers, and pipelines. X-rays are used to enhance public safety by checking airline baggage.
6. Radionuclides are used extensively in conducting various scientific, industrial, bio-medical, pharmaceutical, and agricultural research. They are used in the development of hardier and higher-yielding seed varieties of rice, soybeans, barley, tomatoes, onions, peanuts, and other crops. They are also used for food irradiation to prevent illness caused by E. coli.
7. The military uses radionuclides in gauges, compasses, and field communication equipment.

Radioactive waste is a by-product of industrial use of sources; nuclear power generation; medical research; diagnosis and therapy; manufacture and usage of radioactive materials; and various kinds of scientific research.

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