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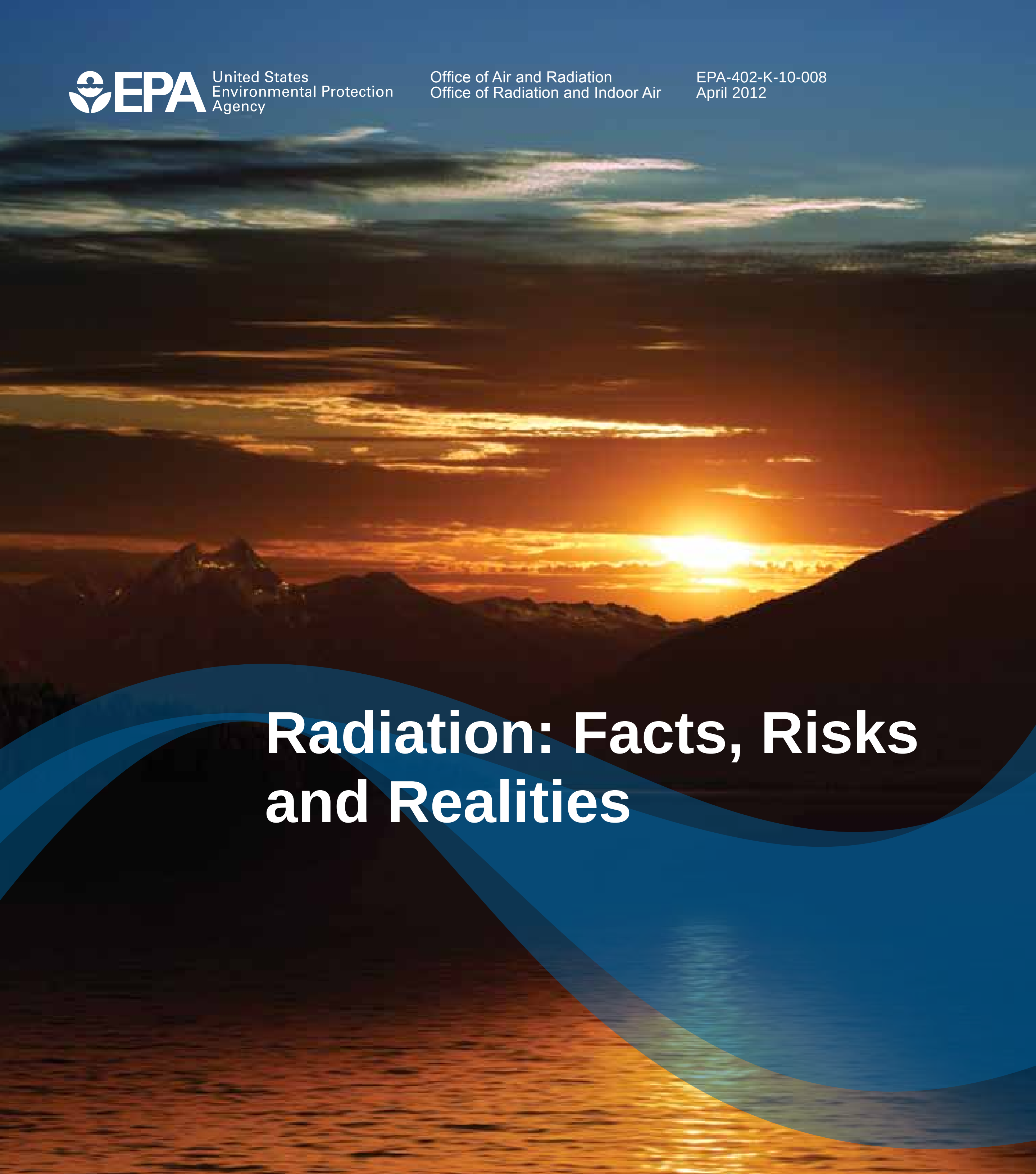

United States
Environmental Protection
Agency

Office of Air and Radiation
Office of Radiation and Indoor Air

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Radiation: Facts, Risks and Realities

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Introduction

While radiation is a term that most people have heard, the basic facts about radiation are much less familiar. The U.S. Environmental Protection Agency (EPA) is responsible for advising the government on radiation hazards and regulating certain sources of radioactivity in the environment. This booklet provides basic facts about radiation science, as well as information on the risks and realities of radiation exposure.

What is Radiation?

Radiation is energy. It can come from unstable atoms or it can be produced by machines. Radiation travels from its source in the form of energy waves or energized particles.

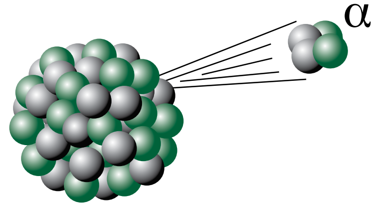
There are actually two kinds of radiation, and one is more energetic than the other. It has so much energy it can knock electrons out of atoms, a process known as ionization. This *ionizing radiation* can affect the atoms in living things, so it poses a health risk by damaging tissue and DNA in genes. While there are other, less energetic, types of *non-ionizing radiation* (including radio waves, microwaves—and visible light), this booklet is about ionizing radiation.

In the late 1800s, Marie and Pierre Curie were among the first to study certain elements that gave off radiation. They described these elements as *radio-actif*, the property that is now called “radioactivity.” As scientists studied radioactivity more closely, they discovered that radioactive atoms are naturally unstable. In order to become stable, radioactive atoms emit particles and/or energy waves. This process came to be known as *radioactive decay*. The major types of ionizing radiation emitted during radioactive decay are alpha particles, beta particles and gamma rays. Other types, such as x-rays, can occur naturally or be machine-produced.

Scientists have also learned that radiation sources are naturally all around us. Radiation can come from as far away as outer space and from as near as the ground that you are standing on. Because it is naturally all around us, we cannot eliminate radiation from our environment. We can, however, reduce our health risks by controlling our exposure to it.

Types of Ionizing Radiation

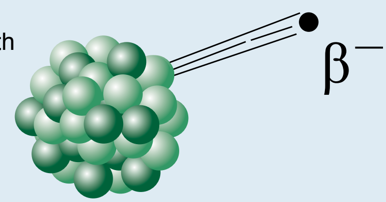
Alpha Particles



Some unstable atoms emit alpha particles (α). Alpha particles are positively charged and made up of two protons and two neutrons from the atom's nucleus, as shown in the illustration at the right. Alpha particles come from the decay of the heaviest radioactive elements, such as uranium, radium and polonium. Even though alpha particles are very energetic, they are so heavy that they use up their energy over short distances and are unable to travel very far from the atom.

The health effect from exposure to alpha particles depends greatly on how a person is exposed. Alpha particles lack the energy to penetrate even the outer layer of skin, so exposure to the outside of the body is not a major concern. Inside the body, however, they can be very harmful. If alpha-emitters are inhaled, swallowed, or get into the body through a cut, the alpha particles can damage sensitive living tissue. The way these large, heavy particles cause damage makes them more dangerous than other types of radiation. The ionizations they cause are very close together--they can release all their energy in a few cells. This results in more severe damage to cells and DNA.

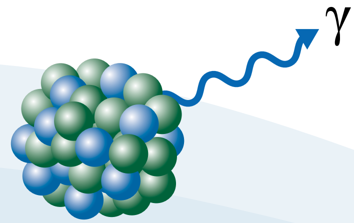
Beta Particles



Beta particles (β) are small, fast-moving particles with a negative electrical charge that are emitted from an atom's nucleus during radioactive decay. These particles are emitted by certain unstable atoms such as hydrogen-3 (tritium), carbon-14 and strontium-90.

Beta particles are more penetrating than alpha particles but are less damaging to living tissue and DNA because the ionizations they produce are more widely spaced. They travel farther in air than alpha particles, but can be stopped by a layer of clothing or by a thin layer of a substance such as aluminum. Some beta particles are capable of penetrating the skin and causing damage such as skin burns. However, as with alpha-emitters, beta-emitters are most hazardous when they are inhaled or swallowed.

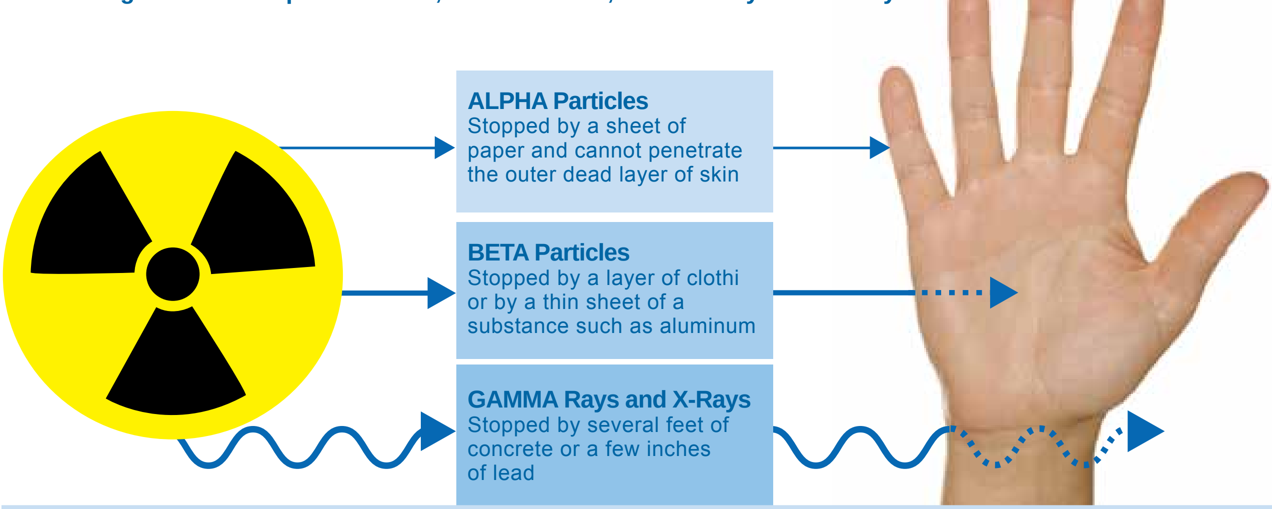
Gamma Rays



Gamma rays (γ) are weightless packets of energy called photons. Unlike alpha and beta particles, which have both energy and mass, gamma rays are pure energy. Gamma rays are similar to visible light, but have much higher energy. Gamma rays are often emitted along with alpha or beta particles during radioactive decay.

Gamma rays are a radiation hazard for the entire body. They can easily penetrate barriers, such as skin and clothing that can stop alpha and beta particles. Gamma rays have so much penetrating power that several inches of a dense material like lead or even a few feet of concrete may be required to stop them. Gamma rays can pass completely through the human body easily; as they pass through, they can cause ionizations that damage tissue and DNA.

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



X-Rays

Because of their use in medicine, almost everybody has heard of x-rays. X-rays are similar to gamma rays in that they are photons of pure energy. X-rays and gamma rays have the same basic properties but come from different parts of the atom. X-rays are emitted from processes outside the nucleus, but gamma rays originate inside the nucleus. They also are generally lower in energy and, therefore, less penetrating than gamma rays. X-rays can be produced naturally or artificially by machines using electricity.

Literally thousands of x-ray machines are used daily in medicine. Computerized tomography, commonly known as CT or CAT scans, uses special x-ray equipment to make detailed images of bones and soft tissue in the body. Medical x-rays are the single largest source of man-made radiation exposure. X-rays are also used in industry for inspections and process controls.

A CT scan uses multiple x-rays to give doctors a three-dimensional image that they can use to diagnose patients.

Understanding Radiation Risks

Radiation can damage living tissue by changing cell structure and damaging DNA. The amount of damage depends upon the type of radiation, its energy and the total amount of radiation absorbed. Also, some cells are more sensitive to radiation. Because damage is at the cellular level, the effect from small or even moderate exposure may not be noticeable. Most cellular damage is repaired. Some cells, however, may not recover as well as others and could become cancerous. Radiation also can kill cells.

The most important risk from exposure to radiation is cancer. Much of our knowledge about the risks from radiation is based on studies of more than 100,000 survivors of the atomic bombs at Hiroshima and Nagasaki, Japan, at the end of World War II. Other studies of radiation industry workers and studies of people receiving large doses of medical radiation also have been an important source of knowledge. Scientists learned many things from these studies.

The most important are:

- The higher the radiation dose, the greater the chance of developing cancer.
- The chance of developing cancer, not the seriousness of the cancer, increases as the radiation dose increases.
- Cancers caused by radiation do not appear until years after the radiation exposure.
- Some people are more likely to develop cancer from radiation exposure than others.

Radiation can damage health in ways other than cancer. It is less likely, but damage to genetic material in reproductive cells can cause genetic mutations, which could be passed on to future generations. Exposing a developing embryo or fetus to radiation can increase the risk of birth defects.

Although such levels of exposure rarely happen, a person who is exposed to a large amount of radiation all at one time could become sick or even die within hours or days. This level of exposure would be rare and can happen only in extreme situations, such as a serious nuclear accident or a nuclear attack.

Determining Radiation Limits

Current science suggests there is some risk from any exposure to radiation. However, it is very hard to tell whether a particular cancer was caused by very low doses of radiation or by something else. While experts disagree over the exact definition and effects of "low dose," U.S. radiation protection standards are based on the premise that any radiation exposure carries some risk.

Naturally Occurring (Background) Radiation

Radon

Radon is a colorless, odorless, tasteless radioactive gas that comes from the decay of radium, which is present in nearly all rocks and soils. Most of our exposure to naturally occurring radiation is from indoor radon. Since radon gas emits alpha particles, inhaling it can cause cancer. Radon can seep into buildings from the ground through cracks and other openings in floors or walls. Accumulated radon in buildings can pose a health hazard.

For more information about radon, its risks, and what you can do to protect yourself, or to obtain a free copy of EPA's "A Citizen's Guide to Radon," visit www.epa.gov/radon, call the National Radon Hotline at 1-800-SOS-RADON or contact your state's radon office.

Radon causes an estimated 20,000 lung cancer deaths each year. The Surgeon General has warned that radon is the second leading cause of lung cancer in the United States. Only smoking causes more lung cancer deaths. A smoker living in a home with high radon levels has an especially high risk of lung cancer.

Radon in the air is measured in picocuries per liter (pCi/L). When radon levels reach 4 pCi/L or higher, the EPA and the U.S. Surgeon General recommend that homeowners take action to reduce them. It is estimated that nearly one in 15 American homes has a radon level that should be reduced. The only way to find out about the radon level in any home is to test for it.

Controlling the Risks from Radon Exposure

Testing for radon is easy. There are many kinds of low-cost, "do-it-yourself" radon test kits available by phone, online and in many stores. It takes only a few minutes to set up the kit and then send it in for analysis. Homeowners can also hire a professional to do the testing. High radon levels in a home can be reduced in a variety of ways. The preferred method is called an active soil depressurization system, which is basically a vent pipe with a fan that vents radon (and other soil gases) from beneath the house.

Radiation from the Ground and from Space

Radon is not the only source of naturally occurring radiation. Some exposure to natural radiation comes from other elements in Earth's crust, such as thorium and potassium. The radiation dose from these sources depends on the makeup of the soil and rocks in the local area. Another natural source is cosmic (space) radiation. Earth is constantly exposed to radiation created by processes occurring in the sun, other stars and in outer space.

Exposure to cosmic radiation depends largely on elevation. Exposure increases as you rise farther above sea level to where the atmosphere is thinner. For example, people who live in Denver, Colorado, which is more than 5,000 feet above sea level, are exposed to more cosmic radiation than people living in Chicago, Illinois, which is approximately 700 feet above sea level.

Man-Made Radiation

Radiation in Medicine

Today, nearly half of the exposure of the U.S. population to radiation comes from medical sources according to the National Council on Radiation Protection and Measurements (NCRP). Most medical exposure comes from the use of standard x-rays and CT scans to diagnose injuries and diseases in patients. Drugs with radioactive material attached, known as radiopharmaceuticals, also are used to diagnose some diseases. These procedures are an important tool to help doctors save lives through quick and accurate diagnoses.

Also, other procedures, such as radiation therapy, use radiation to treat patients. One-third of all successful cancer treatments involve radiation. Carefully targeted radiation beams and certain radiopharmaceuticals destroy cancerous cells while limiting damage to nearby healthy cells.

Controlling the Risks of Medical Radiation

The Nuclear Regulatory Commission (NRC), the Food and Drug Administration (FDA) and other federal and state agencies issue regulations and guidelines to ensure that technicians and equipment meet standards for minimizing radiation exposure. When prescribed appropriately, the benefits of medical radiation outweigh the risks.

Radiation in Industry and Commerce

Nuclear Power

Nuclear power reactors, which use uranium as fuel, supply the United States with about 20 percent of its electricity. Nuclear power plant operations are tightly controlled, making nuclear energy responsible for only a very small part of the public's overall exposure to radiation.

Industrial and Commercial Uses of Radiation

Industries use radiation in a variety of ways. For example, industrial radiography uses x-rays to check for weak points in metal parts and welds before products are sold. Other examples of the use of radiation in industry include irradiators (machines used to kill bacteria and other pathogens in food and other items), devices that test the density of highway and construction materials, research reactors, and security screening at airports and shipping ports.

Controlling the Risks from Nuclear Materials in Industry and Commerce

Several agencies regulate the use of radioactive materials in industry. NRC and authorized state radiation programs issue licenses to companies to use radioactive materials and require special safety measures for their use, storage and disposal. The Occupational Safety and Health Administration (OSHA) issues regulations and standards to help protect workers from unsafe handling of radioactive material or equipment that creates radiation such as x-ray machines.

In the event of an emergency involving radioactive material, state and local governments have the first responsibility for protecting the public and the environment. Several federal agencies would respond as well, including EPA; NRC; and the Departments of Homeland Security, Energy, Agriculture, and Health and Human Services. In addition, U.S. nuclear power plants and the communities that surround them must have emergency plans for protecting the public from radiation exposure in the event of an accidental release of radioactive material into the environment.

Radioactive Waste

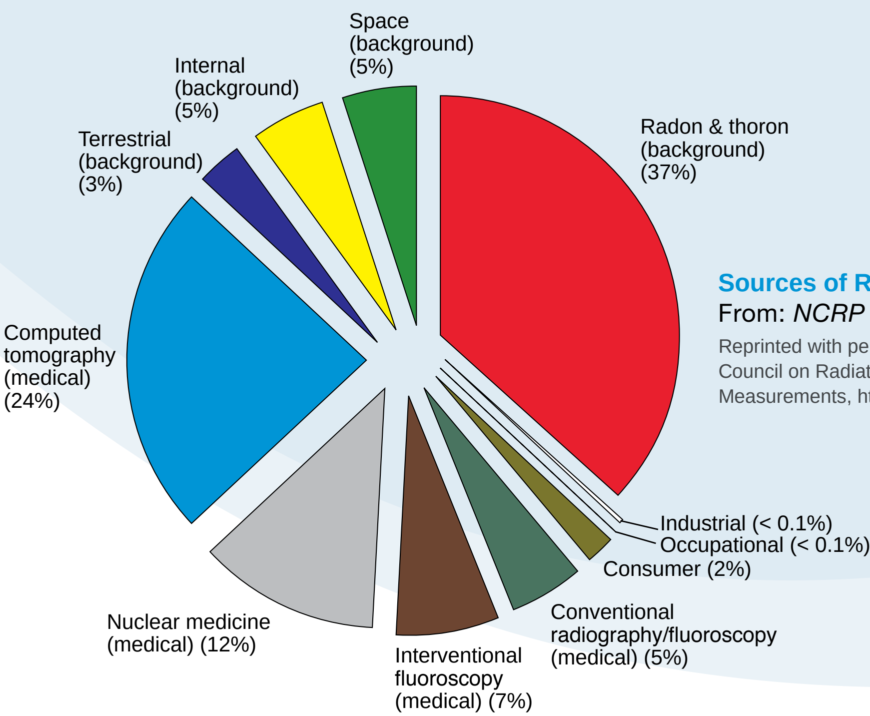
Any activity that produces or uses radioactive material generates radioactive waste. Examples include: nuclear power generation, defense weapons production, nuclear medicine, mining, oil and gas production and scientific research. Depending on the material it contains, this waste can remain radioactive for periods ranging from a few days to billions of years.

Controlling Radioactive Waste

Radioactive wastes must be managed and disposed of properly. Federal agencies and some states control the risks that come with radioactive waste by setting limits and regulations that disposal facilities must follow. EPA is responsible for setting environmental standards that are used by other federal and state agencies in regulations for the disposal of radioactive waste.

Exposure to Ionizing Radiation

In 2009 the National Council on Radiation Protection and Measurements (NCRP) published a study of the U.S. population's exposure to radiation. The chart below shows sources that contributed to an annual average dose of 620 millirem (6.2 millisieverts) per person (millirem and millisievert are units of radiation dose). This is a national average: individual exposures will vary depending on factors such as altitude (space), local soils (radon and thoron), and the number of nuclear medicine procedures or x-rays received.



Sources of Radiation Exposure

From: *NCRP Report No. 160*

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Regulating Radiation Use

States

The states have agencies responsible for regulating the use of radiation and for responding to radiation questions and problems. State agencies are the best, first source of information about radiation issues. States also regulate the use of x-ray machines. Some also are responsible for regulating other sources of radiation within the state on behalf of federal agencies such as the NRC.

U.S. Environmental Protection Agency (EPA)

EPA issues standards and guidelines to limit human exposure to radiation. EPA works directly with the public and industry, the states, and other government agencies to inform people about radiation's risks and to promote actions that reduce human exposure. EPA measures environmental levels of radiation and assesses radiation's effects on people and the environment.

U.S. Nuclear Regulatory Commission (NRC)

NRC develops regulations based on EPA's standards for protecting the public from radiation. NRC regulates the civilian uses of nuclear materials in the United States by licensing facilities that possess, use, or dispose of nuclear materials; establishing standards; and inspecting licensed facilities. NRC regulates nuclear power plants and other users of nuclear materials, including hospitals, educational institutions, research institutions, and industrial equipment such as gauges and testing equipment.

U.S. Department of Homeland Security (DHS)

DHS has the primary responsibility for ensuring that emergency response professionals are prepared to respond to a terrorist attack, natural disaster or other large-scale emergency. DHS coordinates the comprehensive federal response to any large-scale crisis and mounts a recovery effort. Additionally, DHS educates citizens about preparing themselves, their families, and their homes for major emergencies.

U.S. Department of Health and Human Services (HHS)

The HHS Food and Drug Administration's (FDA) Center for Devices and Radiological Health establishes safety standards for x-ray machines and other radiation-producing devices.

U.S. Department of Energy (DOE)

DOE is responsible for the development of the disposal system for spent nuclear fuel from the nation's civilian nuclear power plants. This activity is fully funded by a tax paid by the users of nuclear-generated electricity. DOE is also responsible for the management and disposal of nuclear waste and other radioactive materials associated with nuclear weapons production at federally owned facilities. DOE is cooperating with state governments and private industry in working to clean up its present and former nuclear sites. DOE provides technical advice and assistance to states and the private sector in the management and disposal of low-level radioactive waste.

U.S. Department of Defense (DOD)

While the DOE is responsible for the safe handling of radioactive material at defense production facilities, the DOD is responsible for the safe handling and storage of nuclear weapons in its custody and for other military uses of nuclear energy.

U.S. Department of Transportation (DOT)

The DOT, in cooperation with the NRC and the states, governs the packaging and transport of radioactive materials. The DOT also regulates carriers of radioactive materials.

Occupational Safety and Health Administration (OSHA)

OSHA, a division of the U.S. Department of Labor, develops and enforces radiation protection regulations to protect workers not covered by other agencies.

Suggested Reading

Explore "RadTown" at www.epa.gov/radtown. RadTown is an interactive, virtual community. Each place in RadTown helps you learn about radiation sources or radiation-treated items you might find there.

The following books and websites provide more information on the health effects of radiation exposure.

Basic Information

- Cember, H. ***Introduction to Health Physics. 4th ed.,*** McGraw-Hill Medical, 2008.
- ***"Conference of Radiation Control Program Directors, Inc."*** 2011. Conference of Radiation Control Program Directors. www.crcpd.org
- ***"Health Physics Society."*** 2011. Health Physics Society. www.hps.org
- Martin, A. and Harbison, S.A., ***An Introduction to Radiation Protection. 3rd ed.,*** London: Chapman and Hall, 1987.
- ***"Radiation Protection."*** 2011. U.S. Environmental Protection Agency. www.epa.gov/radiation
- Shapiro, J. ***Radiation Protection. 4th ed.,*** Harvard University Press, 2002.
- Turner, J.F. Atoms, ***Radiation, and Radiation Protection 3rd ed.*** Wiley, 2007.

Advanced Reading

- ***Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2*** The National Academies Press, Washington, DC, 2006.
- ***Ionizing Radiation Exposure of the Population of the United States*** (NCRP Report No. 160): National Council on Radiation Protection and Measurements, 2009.

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