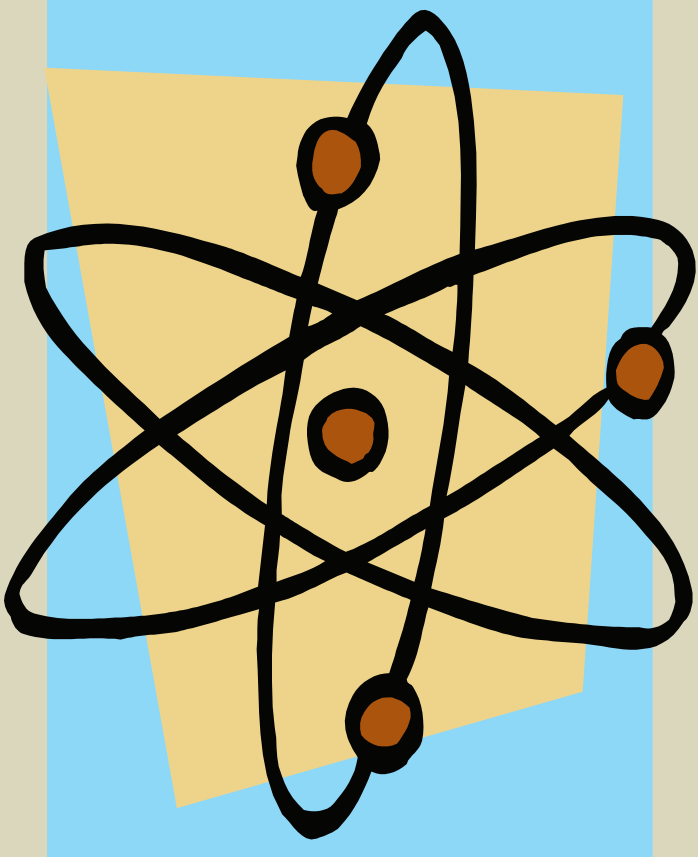
RADIATION AND HEALTH

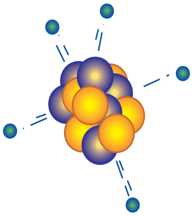


New York State Department of Health

Introduction

Radiation and **radioactive materials** are part of our environment. The radiation in the environment comes from both **cosmic** radiation that originates in outer space, and from radioactive materials that occur naturally in the earth and in our own bodies. Together, these are known as **background** radiation. Everyone is exposed to background radiation daily. In addition, radiation and radioactive materials are produced by many human activities. Radiation is produced by x-ray equipment and by particle accelerators used in research and medicine. Radioactive materials are produced in nuclear reactors and particle accelerators.

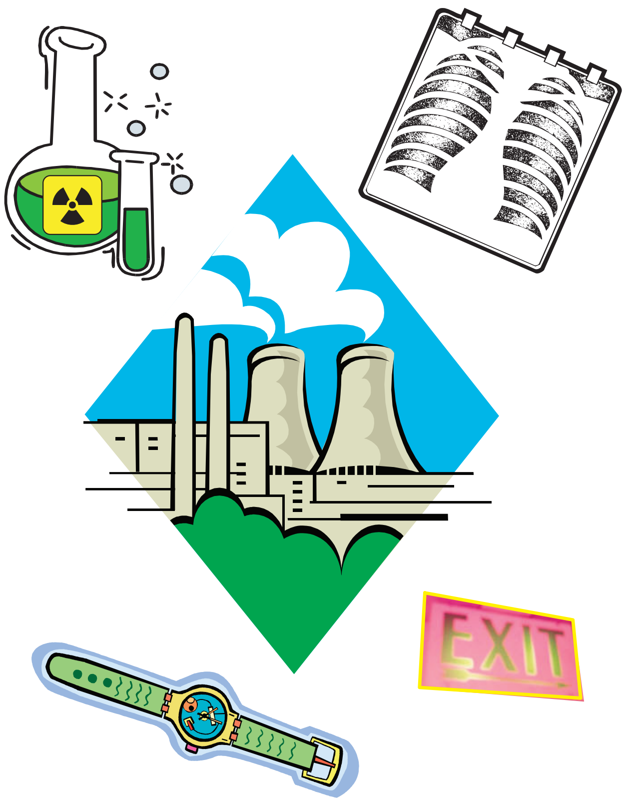
Words in bold are defined in the Glossary on page 16



Radioactive atoms and x-ray equipment produce radiation

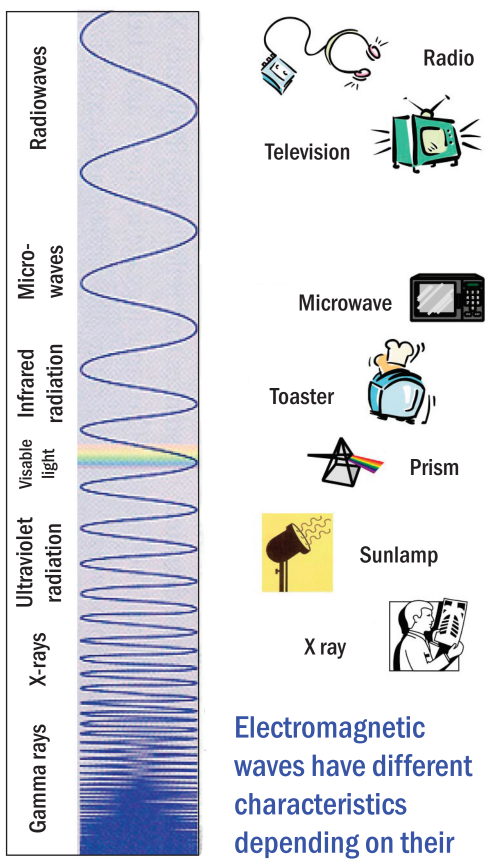
Today, radiation is a common and valuable tool in medicine, research and industry. It is used in medicine to diagnose illnesses, and in high doses, to treat diseases such as cancer. Also, high doses of radiation are used to kill harmful bacteria in food and to extend the shelf life of fresh produce. Radiation produces heat that is used to generate electricity in nuclear power reactors. Radioactive materials are used in a number of consumer products, such as smoke detectors and exit signs, and for many other research and industrial purposes.

Radiation is used in medicine, research, power plants and industry. Many consumer products contain radioactive materials



What is radiation?

Radiation is energy that moves through space or matter at a very high speed. This energy can be in the form of particles, such as **alpha** or **beta** particles, which are emitted from radioactive materials, or waves such as light, heat, radiowaves, microwaves, x-rays and **gamma** rays. Radioactive materials, also known as radionuclides or radioisotopes, are **atoms** that are unstable. In nature, there is a tendency for unstable atoms to change into a stable form. As they change form, they release radiation.



Electromagnetic waves have different characteristics depending on their wave lengths.

Radiation that can produce **ions** when it interacts with matter is called **ionizing radiation**. Ions are the charged particles that are produced when electrons are removed from their positions in the atoms. Alpha particles, beta particles, x-rays and gamma rays are forms of ionizing radiation. On the other hand, radiation that is not capable of producing ions in matter is known as **nonionizing radiation.**

Radiowaves, microwaves, heat waves, visible light and ultraviolet radiation are forms of nonionizing radiation. **This booklet focuses on the health effects of ionizing radiation.** For information on nonionizing radiation, contact the New York State Department of Health at 1-800-458-1158.

How does ionizing radiation affect health?

Ionizing radiation affects health when it causes changes in the cells of the human body. It does this by breaking the chemical bonds that hold together groups of atoms called **molecules.**

For example, **DNA** molecules, which contain a person's genetic information, control the chemical and physical functions of human cells. If damaged, the DNA molecules are able to repair

Radiation affecting DNA molecule

the damage in most cases; but in some instances, damage to DNA molecules will affect the ability of the cells to do their work and to pass information to new cells.

How is the radiation dose measured?

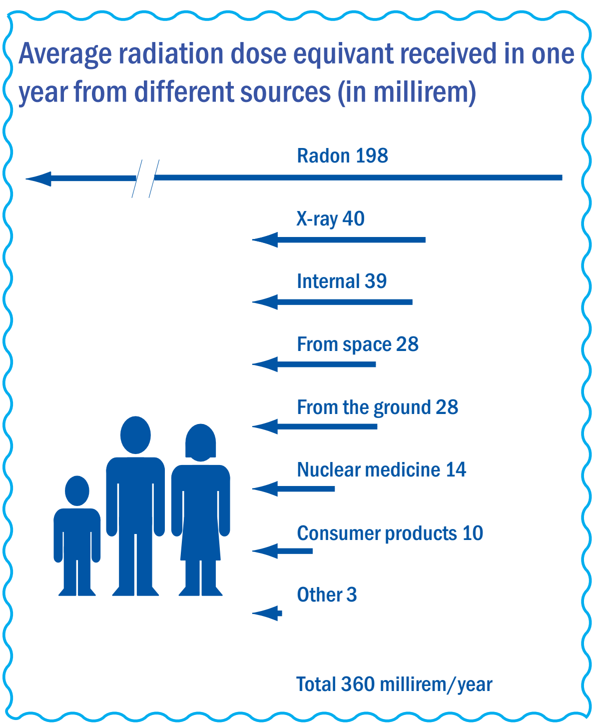
As radiation moves through matter, some of its energy is absorbed into the material. The amount of radiation energy deposited per unit of mass of matter is known as the **absorbed dose.** The unit of measurement for an absorbed dose of radiation is the **rad**. When radiation is absorbed by living tissue, the type of radiation, in addition to the absorbed dose, is important in determining the degree of damage that may occur. Alpha radiation, which is heavier and carries more electric charge, causes more damage than beta or gamma radiation. To account for this difference and to give the dose from all types of radiation a common measure, a quantity known as **dose equivalent** is used. The dose equivalent is found by multiplying the absorbed dose (in rads) by a “quality factor” for the specific type of radiation. The unit for this measurement is called the **rem**. In many cases, the amount of radiation dose equivalent is much less than one rem. So, a smaller unit, the millirem, is used (1 rem = 1,000 millirem).

What is the dose equivalent in the U.S. from all radiation sources?

In the United States, the annual absorbed dose includes exposure to background radiation, indoor radon and different radiation sources (e.g., industrial and medical). The annual dose to individuals varies by where they live and whether they had medical x-ray or nuclear medicine procedures in the past year. On the average, the dose equivalent in the United States from all sources is about 360 millirem per year.

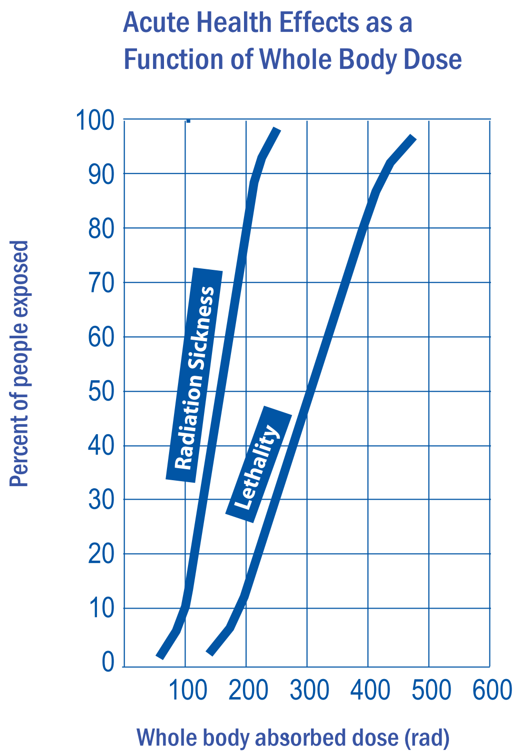
People are exposed to various levels of **radon** gas which occurs naturally in the air that we breathe. Radon in indoor air results in a dose equivalent of about 200 millirem annually, on the average, but can be much higher or lower depending on the radon level in a person's home. Besides radon, the average dose equivalent from **background** radiation to residents of the United States is about 100 millirem per year. About 40 percent of this dose comes from radioactive materials that occur naturally in our bodies. The rest comes from outer space, **cosmic** radiation, or from radioactive materials in the ground.

Another common source of radiation dose is medical x-rays. The dose equivalent from this source varies with the type of examination one receives. For example, a chest x-ray results in a dose equivalent of about 10 millirem; a mammogram about 200-300 millirem; an abdominal examination about 400 millirem); and a CT examination (computed tomography, also called "CAT scan"), between 2,000- and 10,000 millirem. When radiation therapy is used to treat cancer, a very large dose of radiation, about 5,000,000 millirem (or 5,000 rem) is delivered to the tumor site.



Fallout from nuclear weapons tests is another source of radiation exposure. The exposure from this source has decreased with time since atmospheric testing was stopped in the United States in 1962. Now it contributes less than 1 millirem per year.

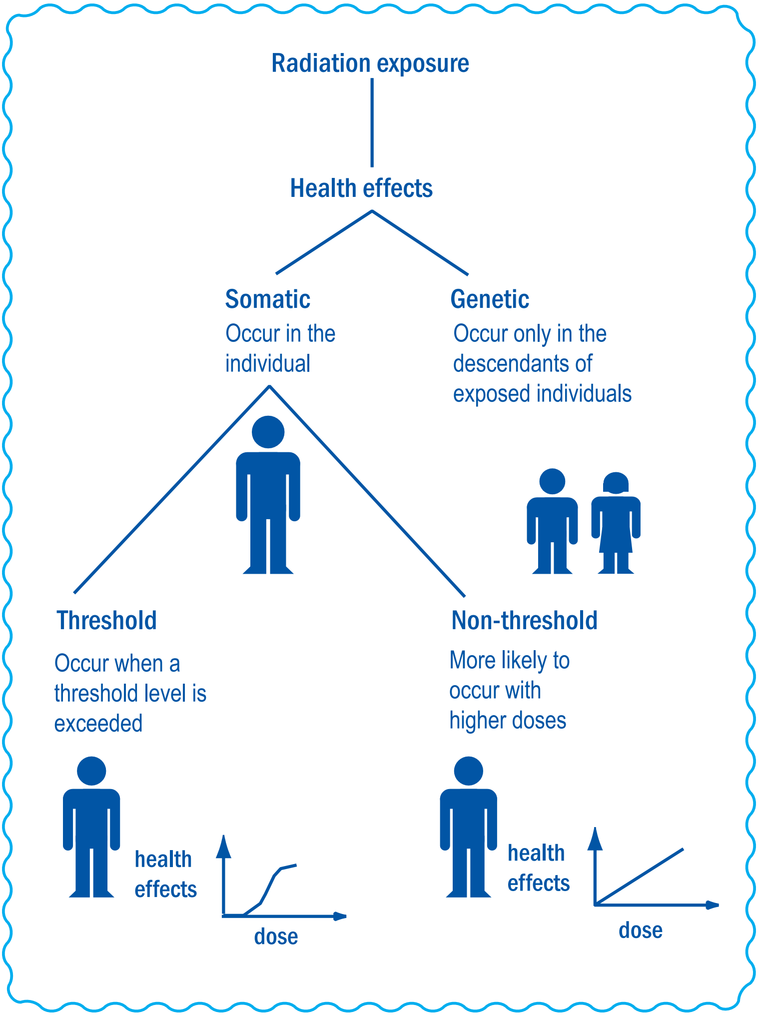
What health effects can be caused by radiation?



A great deal is known about health effects caused by large doses of radiation received in a short period of time.

At high radiation doses, a human cell can be damaged so severely that it will die. At lower doses, the cell can repair the damage and survive. If the repair is faulty, however, the cell could give incorrect information to the new cells it produces.

Exposure to radiation may lead to different health effects. The type and probability of the effects produced generally depend on the radiation dose received.



This could result in health problems for the exposed individuals or in **genetic** defects that may show up in their descendants.

Background radiation is an example of a low dose of radiation and of a low dose rate. A low dose rate occurs when exposure to radiation is spread over a long period of time. Exposure to radiation delivered at low dose rates is generally less dangerous than when the same dose is given all at once because the cell has more time to repair damage to the DNA molecule.

Generally speaking, there are two types of health effects from radiation — **threshold** and **non-threshold** effects.

THRESHOLD EFFECTS

High doses of radiation received in a short period of time result in effects that are noticeable soon after exposure. These are known as threshold effects. A certain dose range must be exceeded before they can occur. These effects include radiation sickness and death, cataracts, sterility, loss of hair, reduced thyroid function and skin radiation burns. The severity of these effects increases with the size of the dose.

Radiation Sickness – At doses of about 60 rem, 5% of exposed individuals may vomit. This increases to about 50% at 200 rem. At doses between 300 and 400 rem and without medical treatment, there is a 50% chance that a person will die within 60 days. With proper medical care, however, some people exposed to 1,000 rem could survive.

Cataracts – A single exposure between 200 and 500 rem could cause cataracts (clouding of the lens of the eye). If an exposure took place over a period of months, however, it would take about a total of 1,000 rem to produce a cataract.

Sterility – In men, a single dose of 15 rem can cause temporary sterility, and a single dose between 400 and 500 rem can cause permanent sterility. In women, a total dose of 400 rem received over two or three exposures has been known to cause permanent sterility.

Fetal Effects – A number of threshold effects can result from high doses, depending on the stage of development of the fetus. Fetal death is most likely in the first 2 weeks after conception. During this period, a dose of 10 rem may increase the risk of a fetal death by about 0.1 to 1 percent. Cataracts, malformations, and mental and growth retardation can occur as a result of high radiation doses received 3 to 7 weeks after conception. These effects were not observed at doses of 10 rem or less. Exposures 8 to 15 weeks after conception may lead to mental retardation if the total dose is more than 20 rem. Also, a study of atomic bomb survivors in Japan showed that exposure between 8 and 15 weeks after conception resulted in lower IQ scores in the exposed children. It is estimated that an absorbed dose of 100 rads lowers the IQ score by about 30 points.

NON-THRESHOLD EFFECTS

There are other health effects of radiation that generally do not appear until years after an exposure. It is assumed that there are no threshold doses for these effects and that any radiation exposure can increase a person's chances of having these effects. These are called non-threshold effects. While the chances of these delayed effects occurring increase with the size of the dose, the severity does not. They can occur in the person who receives the radiation dose or in that person's offspring. In the latter case, they are known as genetic effects.

Genetic Effects – No increase of genetic effects from radiation exposure have been found in humans. However, there have been a number of animal studies that have shown that exposure to fairly high doses of radiation increases the chances of genetic effects in the offspring of the exposed animals. They also indicate that radiation does not cause any unique effects. Rather, it increases the number of genetic effects that are normally seen in unexposed animals.

Even though genetic effects have not been found to increase in exposed human populations, it is safer to assume that there is an increased chance of these effects, even at low radiation doses.

Fetal Effects – The embryo/fetus is particularly sensitive to radiation. Some studies have shown increases in the rates of childhood cancer in children exposed to radiation before birth.

Cancer – Cancer is the most common non-threshold effect of high radiation doses in humans. The cancers caused by radiation are no different from cancers due to other causes.

What is the source of information on radiation-induced cancer?

Estimates of cancer risk for specific doses of radiation are based on many studies of groups of people who were exposed to high doses of radiation. These include the survivors of the atomic bombings in Japan, people who were exposed to radiation for medical reasons, and workers who were exposed to high doses of radiation on the job.

The survivors of the World War II atomic bomb explosions in Hiroshima and Nagasaki were exposed to an average radiation dose equivalent of 24 rem, and their health has been carefully studied since 1950. This study is the most important source of information on the risk of cancer from radiation exposure because it involves a large number of individuals who received whole body radiation exposure. It provides information on the risk of increased cancer to all organs and on the variation of risk with age at the time of exposure.

Are all tissues and organs equally sensitive to radiation?

Radiation has been found to induce cancer in most body tissues and organs. Different tissues and organs, however, show varying degrees of sensitivity. The tissues and organs showing high sensitivity include bone marrow (leukemia), breasts, thyroid glands and lungs. In contrast, there is no clear evidence that radiation causes cancer of the cervix or prostate.

Human tissues and organs ranked by sensitivity to radiation induced cancer

High	Moderate	Low
Bone marrow	Stomach	Brain
Breast (premenopausal)	Ovary	Bone
Thyroid (child)	Colon	Uterus
Lung	Bladder	Kidney
	Skin	Esophagus
		Liver

Are all people at equal risk?

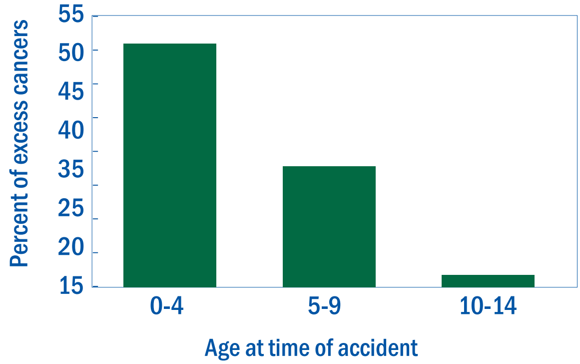
Some people are more sensitive to harmful effects of radiation than others. There are a number of factors that influence an individual's sensitivity to radiation. These factors include age, gender, other exposures and genetic factors.

Age – In general, exposed children are more at risk than adults. Breast cancer risk among women exposed to radiation is greatest among women who were exposed before age 20, and least when exposure occurred after menopause. Also, exposed children are at greater risk of radiation-induced thyroid cancer than adults.

Gender – In women, the risk of breast and ovarian cancers from radiation is high, but there is no clear evidence that radiation causes breast or prostate cancers in men. Females are also seen to have more radiation induced thyroid cancer than males.

Other Exposures – Underground miners exposed to high levels of radon have increased risk of lung cancer, and those who smoke have an even greater risk. Exposure to ultraviolet radiation from the sun following the use of x-rays to treat scalp ringworm conditions increases the risk of developing skin cancer in the area of the skin exposed to both types of radiation.

Genetic Factors – Individuals with certain pre-existing genetic diseases have increased sensitivity to radiation, especially if they receive radiation therapy. For example, Age dependence of childhood cancers following Chernobyl



children genetically predisposed to cancer of the retina (retinoblastoma) and who are treated with radiation are at increased risk of developing bone cancer following treatment. Patients with ataxia telangiectasia (AT), a rare genetic disorder, are unusually sensitive to tissue damage from radiation therapy, but there is no clear evidence that they are at increased risk of radiation induced cancer.

What is the risk of death from cancers caused by radiation exposure?

In the 1990 report **Health Effects of Exposures to Low Levels of Ionizing Radiation – BEIR V,** The National Research Council estimated that the excess lifetime risk of fatal cancer following a single exposure to 10 rem would be 0.8 percent. This means that if 1,000 people were exposed to 10 rem each, 8 would be expected to die of cancer induced by the radiation. These deaths are in addition to about 220 cancer deaths that result from other causes. If the 10 rem were received over a period of weeks or months, the extra lifetime risk could be reduced to 0.5 percent. These risk factors are average values for a population similar to that of the United States.

These percentages are not precise predictions of risk, especially at low radiation doses and dose rates. At doses comparable to natural background radiation (0.1 rem per year), the risk could be higher than these estimates, but it could also be lower or even non-existent.

Is there a cancer risk from any radiation exposure?

The risk of increased cancer incidence is well established for doses above 10 rem. For low doses, it has not been possible to scientifically determine if an increased risk exists, but many scientists believe that small doses of radiation do lead to increased cancer risk, and that the degree of risk is directly proportional to the size of the dose. Risk estimates from low doses are obtained by extrapolation from high dose observations.

How is the public protected from radiation risks?

Because of the potential for harm from exposure to radiation, radiation protection programs are designed to protect both workers and the general public, their descendants and the environment, while still allowing society to benefit from the many valuable uses of radiation. Current radiation protection systems are based on the following principles:

- The benefit must outweigh the risk. Radiation exposure must produce a net positive benefit.
- The amount of exposure must be limited. Radiation doses to individuals cannot exceed limits set by state and federal agencies.
- All radiation exposures and releases to the environment must be kept **as low as reasonably achievable,** below regulatory limits.

All users of radiation sources in New York State are regulated by state, federal and local government agencies. Users are required to implement radiation safety programs that reflect these principles. They are routinely inspected to assure that all operations are carried out safely.

What can an individual do to reduce radiation exposure?

Exposure to indoor radon contributes a large portion of the total average dose. Measurements of radon in New York State homes made since 1985 have identified many areas with elevated indoor radon levels. Exposure can be reduced by testing the home for radon and implementing measures to reduce radon levels, if necessary. For additional information on radon, its measurement and mitigation, contact the New York State Department of Health at 1-800-458-1158.

Also, a person should receive only x-ray examinations that his or her health care provider thinks are truly necessary for an accurate diagnosis. Alternative, non–x-ray tests should be used instead, if available. However, one should not refuse an x-ray examination that a doctor feels is necessary.

Are there new areas of research that will add to our knowledge of radiation risks?

Recent advances in molecular genetics and microbiology have increased our understanding of cancer development. It is hoped that further research will provide additional information on the risk of radiation-induced cancer and genetic effects, especially at low doses.

GLOSSARY

Absorbed Dose is the amount of radiation absorbed in matter measured in terms of energy per unit mass. The unit traditionally used for absorbed dose is the “rad,” but a new unit called a “gray” has been introduced for international use and will eventually replace the rad. One gray equals 100 rads.

Alpha Particles are charged particles that are emitted from some radioactive materials such as radium and radon. The electric charge and mass of the alpha particle are the same as those of the nucleus of a helium atom.

As Low As Reasonably Achievable means making every reasonable effort to keep exposures to radiation as far below as practical the dose limits set in the regulations, taking into consideration the state of technology and other societal and economic considerations.

Atoms are the smallest particles of chemical elements that cannot be divided or broken up by chemical means. Each atom has a large nucleus that contains protons and neutrons, and carries a positive charge equal to the number of protons. Orbiting the nucleus are negatively charged electrons equal in number to the protons in the nucleus.

Background Radiation is radiation that results from natural sources. This includes cosmic radiation and naturally-occurring radioactive materials in the ground and the earth’s atmosphere including radon.

Beta Particle is a charged particle emitted from the nucleus of a radioactive material. Beta particles have an electric charge and mass that are equal to those of an electron.

Cosmic Radiation is radiation that originates in outer space and filters through the earth’s atmosphere.

DNA is deoxyribonucleic acid. This is a molecule that controls the chemical and physical functions of cells. In DNA, a cell passes on information to subsequent generations of cells (daughter cells).

Dose Equivalent is the absorbed dose (in rads or Grays) multiplied by a "quality factor" for the type of radiation in question. This factor is used because some types of radiation are more biologically damaging than others. The unit of dose equivalent is the rem if the absorbed dose is measured in rads. However, if the dose is measured in Grays, a new unit of dose equivalent called the Sievert is used. One Sievert equals 100 rem.

Dose Rate is the radiation dose received over a specified period of time.

Electrons are negatively charged particles that determine the chemical properties of an atom.

Fallout is the airborne radioactive debris from nuclear weapons explosions that has been deposited on the earth.

Gamma Rays are electromagnetic energy that is emitted by a radioactive material. Gamma rays have no mass or electric charge.

Genetic Effects are changes in cells in either the sperm or the egg that are passed on to children born to the exposed individual. If the child survives and becomes a parent, the genetic fault will be passed on to future generations.

Ionizing Radiation is radiation that removes electrons from the atoms it meets, causing them to become electrically charged ions.

Ions are charged atoms that have too few or too many electrons compared to the number of protons, resulting in a positive or negative charge.

Millirem is a unit of measurement equal to 1/l,000th of a rem (1 rem = 1,000 millirem).

Molecules are groups of atoms held together by chemical forces.

Nonionizing Radiation is radiation that is not capable of removing electrons from the atoms it encounters. Examples include visible, ultraviolet and infrared light, and radio waves.

Rad (radiation absorbed dose) is the unit of measurement for the amount or dose of ionizing radiation absorbed by any material.

Radiation is energy that moves through space or matter at a very high speed.

Radioactive Material is material that contains an unstable atomic nucleus and releases radiation in the process of changing to a stable form.

Radium is a naturally occurring radioactive element that occurs in soil. Discovered by Marie and Pierre Curie in 1898, radium was used in radiation therapy and in luminous paints.

Radon is a naturally occurring radioactive element that is produced when radium decays. Radon exists as a gas and is present in the soil. It seeps into the air and can become concentrated in enclosed spaces such as houses. A high radiation dose can result when air containing radon is inhaled.

Rem (roentgen equivalent man) is the unit of measurement for the dose equivalent (the dose of ionizing radiation multiplied by a “quality factor”).

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Information on radiation and health can be obtained from the following web sites:

Conference of Radiation Control Program Directors
www.crcpd.org

National Cancer Institute
www.nci.nih.gov

National Academy of Sciences
www.nas.edu

National Council on Radiation Protection
www.ncrp.com

Radiation and Health Physics Homepage
www.umich.edu/~radinfo

US Department of Energy
www.doe.gov

US Environmental Protection Agency
www.epa.gov

US Food & Drug Administration
www.fda.gov

US Nuclear Regulatory Commission
www.nrc.gov

Health Physics Society
www.hps.org

International Atomic Energy Agency
www.iaea.or.at

International Radiation Protection Association
http://www.irpa.net/

For further information, contact

New York State Department of Health
Center for Environmental Health
Bureau of Environmental Radiation Protection
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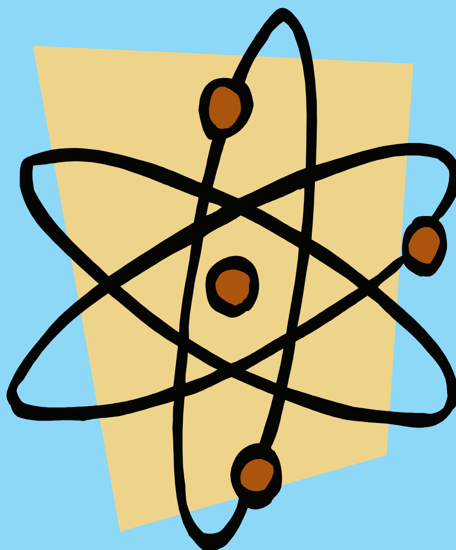

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