Glossary of Radiological Terms

Absolute risk: the proportion of a population expected to get a disease over a specified time period. *See also* risk, relative risk.

Absorbed dose: the amount of energy deposited by ionizing radiation in a unit mass of tissue. It is expressed in units of joule per kilogram (J/kg), and called "gray" (Gy). *For more information, see* "Primer on Radiation Measurement" *at the end of this document.*

Activity (radioactivity): the rate of decay of radioactive material expressed as the number of atoms breaking down per second measured in units called becquerels or curies.

Acute exposure: an exposure to radiation that occurred in a matter of minutes rather than in longer, continuing exposure over a period of time. *See also* chronic exposure, exposure, fractionated exposure.

Acute Radiation Syndrome (ARS): a serious illness caused by receiving a dose greater than 50 rads of penetrating radiation to the body in a short time (usually minutes). The earliest symptoms are nausea, fatigue, vomiting, and diarrhea. Hair loss, bleeding, swelling of the mouth and throat, and general loss of energy may follow. If the exposure has been approximately 1,000 rads or more, death may occur within 2 – 4 weeks. *For more information, see CDC's fact sheet* "Acute Radiation Syndrome" *at* http://www.bt.cdc.gov/radiation/ars.asp.

Air burst: a nuclear weapon explosion that is high enough in the air to keep the fireball from touching the ground. Because the fireball does not reach the ground and does not pick up any surface material, the radioactivity in the fallout from an air burst is relatively insignificant compared with a surface burst. *For more information, see Chapter 2 of CDC's Fallout Report at* http://www.cdc.gov/nceh/radiation/fallout/falloutreport.pdf.

Alpha particle: the nucleus of a helium atom, made up of two neutrons and two protons with a charge of +2. Certain radioactive nuclei emit alpha particles. Alpha particles generally carry more energy than gamma or beta particles, and deposit that energy very quickly while passing through tissue. Alpha particles can be stopped by a thin layer of light material, such as a sheet of paper, and cannot penetrate the outer, dead layer of skin. Therefore, they do not damage living tissue when outside the body. When alpha-emitting atoms are inhaled or swallowed, however, they are especially damaging because they transfer relatively large amounts of ionizing energy to living cells. *See also* beta particle, gamma ray, neutron, x-ray.

Ambient air: the air that surrounds us.

Americium (Am): a silvery metal; it is a man-made element whose isotopes Am-237 through Am-246 are all radioactive. Am-241 is formed spontaneously by the beta decay of plutonium-241. Trace quantities of americium are widely used in smoke detectors, and as neutron sources in neutron moisture gauges.

Atom: the smallest particle of an element that can enter into a chemical reaction.

Atomic number: the total number of protons in the nucleus of an atom.

Atomic mass unit (amu): 1 amu is equal to one twelfth of the mass of a carbon-12 atom.

Atomic mass number: the total number of protons and neutrons in the nucleus of an atom.

Atomic weight: the mass of an atom, expressed in atomic mass units. For example, the atomic number of helium-4 is 2, the atomic mass is 4, and the atomic weight is 4.00026.

Background radiation: ionizing radiation from natural sources, such as terrestrial radiation due to radionuclides in the soil or cosmic radiation originating in outer space.

Becquerel (Bq): the amount of a radioactive material that will undergo one decay (disintegration) per second. *For more information, see* "Primer on Radiation Measurement" *at the end of this document*.

Beta particles: electrons ejected from the nucleus of a decaying atom. Although they can be stopped by a thin sheet of aluminum, beta particles can penetrate the dead skin layer, potentially causing burns. They can pose a serious direct or external radiation threat and can be lethal depending on the amount received. They also pose a serious internal radiation threat if beta-emitting atoms are ingested or inhaled. *See also* alpha particle, gamma ray, neutron, x-ray.

Bioassay: an assessment of radioactive materials that may be present inside a person's body through analysis of the person's blood, urine, feces, or sweat.

Biological Effects of Ionizing Radiation (BEIR) Reports: reports of the National Research Council's committee on the Biological Effects of Ionizing Radiation. *For more information, see* http://www.nap.edu/books/0309039959/html/.

Biological half-life: the time required for one half of the amount of a substance, such as a radionuclide, to be expelled from the body by natural metabolic processes, not counting radioactive decay, once it has been taken in through inhalation, ingestion, or absorption. *See also* radioactive half-life, effective half-life.

Carcinogen: a cancer-causing substance.

Chain reaction: a process that initiates its own repetition. In a fission chain reaction, a fissile nucleus absorbs a neutron and fissions (splits) spontaneously, releasing additional neutrons. These, in turn, can be absorbed by other fissile nuclei, releasing still more neutrons. A fission chain reaction is self-sustaining when the number of neutrons released in a given time equals or exceeds the number of neutrons lost by absorption in non-fissile material or by escape from the system.

Chronic exposure: exposure to a substance over a long period of time, possibly resulting in adverse health effects. *See also* acute exposure, fractionated exposure.

Cobalt (Co): gray, hard, magnetic, and somewhat malleable metal. Cobalt is relatively rare and generally obtained as a byproduct of other metals, such as copper. Its most common radioisotope, cobalt-60 (Co-60), is used in radiography and medical applications. Cobalt-60 emits beta particles and gamma rays during radioactive decay.

Collective dose: the estimated dose for an area or region multiplied by the estimated population in that area or region. *For more information, see* "Primer on Radiation Measurement" *at the end of this document*.

Committed dose: a dose that accounts for continuing exposures expected to be received over a long period of time (such as 30, 50, or 70 years) from radioactive materials that were deposited inside the body. *For more information, see* "Primer on Radiation Measurement" *at the end of this document*.

Concentration: the ratio of the amount of a specific substance in a given volume or mass of solution to the mass or volume of solvent.

Conference of Radiation Control Program Directors (CRCPD): an organization whose members represent state radiation protection programs. *For more information, see the CRCPD website:* http://www.crcpd.org.

Contamination (radioactive): the deposition of unwanted radioactive material on the surfaces of structures, areas, objects, or people where it may be external or internal. *See also* decontamination.

Cosmic radiation: radiation produced in outer space when heavy particles from other galaxies (nuclei of all known natural elements) bombard the earth. *See also* background radiation, terrestrial radiation.

Criticality: a fission process where the neutron production rate equals the neutron loss rate to absorption or leakage. A nuclear reactor is "critical" when it is operating.

Critical mass: the minimum amount of fissile material that can achieve a self-sustaining nuclear chain reaction.

Cumulative dose: the total dose resulting from repeated or continuous exposures of the same portion of the body, or of the whole body, to ionizing radiation. *For more information, see* "Primer on Radiation Measurement" *at the end of this document*.

Curie (Ci): the traditional measure of radioactivity based on the observed decay rate of 1 gram of radium. One curie of radioactive material will have 37 billion disintegrations in 1 second. *For more information, see* "Primer on Radiation Measurement" *at the end of this document*.

Cutaneous Radiation Syndrome (CRS): the complex syndrome resulting from radiation exposure of more than 200 rads to the skin. The immediate effects can be reddening and swelling of the exposed area (like a severe burn), blisters, ulcers on the skin, hair loss, and severe pain. Very large doses can result in permanent hair loss, scarring, altered skin color, deterioration of the affected body part, and death of the affected tissue (requiring surgery). *For more information, see CDC's fact sheet* "Acute Radiation Syndrome," *at* http://www.bt.cdc.gov/radiation/ars.asp.

Decay chain (decay series): the series of decays that certain radioisotopes go through before reaching a stable form. For example, the decay chain that begins with uranium-238 (U-238) ends in lead-206 (Pb-206), after forming isotopes, such as uranium-234 (U-234), thorium-230 (Th-230), radium-226 (Ra-226), and radon-222 (Rn-222).

Decay constant: the fraction of a number of atoms of a radioactive nuclide that disintegrates in a unit of time. The decay constant is inversely proportional to the radioactive half-life.

Decay products (or daughter products): the isotopes or elements formed and the particles and high-energy electromagnetic radiation emitted by the nuclei of radionuclides during radioactive decay. Also known as "decay chain products" or "progeny" (the isotopes and elements). A decay product may be either radioactive or stable.

Decay, radioactive: disintegration of the nucleus of an unstable atom by the release of radiation.

Decontamination: the reduction or removal of radioactive contamination from a structure, object, or person.

Depleted uranium: uranium containing less than 0.7% uranium-235, the amount found in natural uranium. *See also* enriched uranium.

Deposition density: the activity of a radionuclide per unit area of ground. Reported as becquerels per square meter or curies per square meter.

Deterministic effects: effects that can be related directly to the radiation dose received. The severity increases as the dose increases. A deterministic effect typically has a threshold below which the effect will not occur. *See also* stochastic effect, non-stochastic effect.

Deuterium: a non-radioactive isotope of the hydrogen atom that contains a neutron in its nucleus in addition to the one proton normally seen in hydrogen. A deuterium atom is twice as heavy as normal hydrogen. *See also* tritium.

Dirty bomb: a device designed to spread radioactive material by conventional explosives when the bomb explodes. A dirty bomb kills or injures people through the initial blast of the conventional explosive and spreads radioactive contamination over possibly a large area—hence the term "dirty." Such bombs could be miniature devices or large truck bombs. A dirty bomb is much simpler to make than a true nuclear weapon. *See also* radiological dispersal device.

Dose (radiation): radiation absorbed by person's body. Several different terms describe radiation dose. *For more information, see* "Primer on Radiation Measurement" *at the end of this document*.

Dose coefficient: the factor used to convert radionuclide intake to dose. Usually expressed as dose per unit intake (e.g., sieverts per becquerel).

Dose equivalent: a quantity used in radiation protection to place all radiation on a common scale for calculating tissue damage. Dose equivalent is the absorbed dose in grays times the quality factor. The quality factor accounts for differences in radiation effects caused by different types of ionizing radiation. Some radiation, including alpha particles, causes a greater amount of damage per unit of absorbed dose than other radiation. The sievert (Sv) is the unit used to measure dose equivalent. *For more information, see* "Primer on Radiation Measurement" *at the end of this document*.

Dose rate: the radiation dose delivered per unit of time.

Dose reconstruction: a scientific study that estimates doses to people from releases of radioactivity or other pollutants. The dose is reconstructed by determining the amount of material released, the way people came in contact with it, and the amount they absorbed.

Dosimeter: a small portable instrument (such as a film badge, thermoluminescent dosimeter [TLD], or pocket dosimeter) for measuring and recording the total accumulated dose of ionizing radiation a person receives.

Dosimetry: assessment (by measurement or calculation) of radiation dose.

Effective dose: a dosimetric quantity useful for comparing the overall health affects of irradiation of the whole body. It takes into account the absorbed doses received by various organs and tissues and weighs them according to present knowledge of the sensitivity of each organ to radiation. It also accounts for the type of radiation and the potential for each type to inflict biologic damage. The effective dose is used, for example, to compare the overall health detriments of different radionuclides in a given mix. The unit of effective dose is the sievert (Sv); 1 Sv = 1 J/kg. *For more information, see* "Primer on Radiation Measurement" *at the end of this document*.

Effective half-life: the time required for the amount of a radionuclide deposited in a living organism to be diminished by 50% as a result of the combined action of radioactive decay and biologic elimination. *See also* biological half-life, decay constant, radioactive half-life.

Electron: an elementary particle with a negative electrical charge and a mass 1/1837 that of the proton. Electrons surround the nucleus of an atom because of the attraction between their negative charge and the positive charge of the nucleus. A stable atom will have as many electrons as it has protons. The number of electrons that orbit an atom determine its chemical properties. *See also* neutron.

Electron volt (eV): a unit of energy equivalent to the amount of energy gained by an electron when it passes from a point of low potential to a point one volt higher in potential.

Element: 1) all isotopes of an atom that contain the same number of protons. For example, the element uranium has 92 protons, and the different isotopes of this element may contain 134 to 148 neutrons. 2) In a reactor, a fuel element is a metal rod containing the fissile material.

Enriched uranium: uranium in which the proportion of the isotope uranium-235 has been increased by removing uranium-238 mechanically. *See also* depleted uranium.

Epidemiology: the study of the distribution and determinants of health-related states or events in specified populations; and the application of this study to the control of health problems.

Exposure (radiation): a measure of ionization in air caused by x-rays or gamma rays only. The unit of exposure most often used is the roentgen. *See also* contamination.

Exposure pathway: a route by which a radionuclide or other toxic material can enter the body. The main exposure routes are inhalation, ingestion, absorption through the skin, and entry through a cut or wound in the skin.

Exposure rate: a measure of the ionization produced in air by x-rays or gamma rays per unit of time (frequently expressed in roentgens per hour).

External exposure: exposure to radiation outside of the body.

Fallout, nuclear: minute particles of radioactive debris that descend slowly from the atmosphere after a nuclear explosion. *For more information, see Chapter 2 of CDC's Fallout Report at* http://www.cdc.gov/nceh/radiation/fallout/falloutreport.pdf.

Fissile material: any material in which neutrons can cause a fission reaction. The three primary fissile materials are uranium-233, uranium-235, and plutonium-239.

Fission (fissioning): the splitting of a nucleus into at least two other nuclei that releases a large amount of energy. Two or three neutrons are usually released during this transformation. *See also* fusion.

Fractionated exposure: exposure to radiation that occurs in several small acute exposures, rather than continuously as in a chronic exposure.

Fusion: a reaction in which at least one heavier, more stable nucleus is produced from two lighter, less stable nuclei. Reactions of this type are responsible for the release of energy in stars or in thermonuclear weapons.

Gamma rays: high-energy electromagnetic radiation emitted by certain radionuclides when their nuclei transition from a higher to a lower energy state. These rays have high energy and a short wave length. All gamma rays emitted from a given isotope have the same energy, a characteristic that enables scientists to identify which gamma emitters are present in a sample. Gamma rays penetrate tissue farther than do beta or alpha particles, but leave a lower concentration of ions in their path to potentially cause cell damage. Gamma rays are very similar to x-rays. *See also* neutron.

Geiger counter: a radiation detection and measuring instrument consisting of a gas-filled tube containing electrodes, between which an electrical voltage but no current flows. When ionizing radiation passes through the tube, a short, intense pulse of current passes from the negative electrode to the positive electrode and is measured or counted. The number of pulses per second measures the intensity of the radiation field. Geiger counters are the most commonly used portable radiation detection instruments.

Genetic effects: hereditary effects (mutations) that can be passed on through reproduction because of changes in sperm or ova. *See also* teratogenic effects, somatic effects.

Gray (Gy): a unit of measurement for absorbed dose. It measures the amount of energy absorbed in a material. The unit Gy can be used for any type of radiation, but it does not describe the biological effects of the different radiations. *For more information, see* "Primer on Radiation Measurement" *at the end of this document*.

Half-life: the time any substance takes to decay by half of its original amount. *See also* biological half-life, decay constant, effective half-life, radioactive half-life.

Health physics: a scientific field that focuses on protection of humans and the environment from radiation. Health physics uses physics, biology, chemistry, statistics, and electronic instrumentation to help protect individuals from any damaging effects of radiation. *For more information, see the Health Physics Society website:* http://www.hps.org/.

High-level radioactive waste: the radioactive material resulting from spent nuclear fuel reprocessing. This can include liquid waste directly produced in reprocessing or any solid material derived from the liquid wastes having a sufficient concentration of fission products. Other radioactive materials can be designated as high-level waste, if they require permanent isolation. This determination is made by the U.S. Nuclear Regulatory Commission on the basis of criteria established in U.S. law. *See also* low-level waste, transuranic waste.

Hot spot: any place where the level of radioactive contamination is considerably greater than the area around it.

Ingestion: 1) the act of swallowing; 2) in the case of radionuclides or chemicals, swallowing radionuclides or chemicals by eating or drinking.

Inhalation: 1) the act of breathing in; 2) in the case of radionuclides or chemicals, breathing in radionuclides or chemicals.

Internal exposure: exposure to radioactive material taken into the body.

Iodine: a nonmetallic solid element. There are both radioactive and non-radioactive isotopes of iodine. Radioactive isotopes of iodine are widely used in medical applications. Radioactive iodine is a fission product and is the largest contributor to people's radiation dose after an accident at a nuclear reactor.

Ion: an atom that has fewer or more electrons than it has protons causing it to have an electrical charge and, therefore, be chemically reactive.

Ionization: the process of adding one or more electrons to, or removing one or more electrons from, atoms or molecules, thereby creating ions. High temperatures, electrical discharges, or nuclear radiation can cause ionization.

Ionizing radiation: any radiation capable of displacing electrons from atoms, thereby producing ions. High doses of ionizing radiation may produce severe skin or tissue damage. *See also* alpha particle, beta particle, gamma ray, neutron, x-ray.

Irradiation: exposure to radiation.

Isotope: a nuclide of an element having the same number of protons but a different number of neutrons.

Kiloton (Kt): the energy of an explosion that is equivalent to an explosion of 1,000 tons of TNT. One kiloton equals 1 trillion (10^{12}) calories. *See also* megaton.

Latent period: the time between exposure to a toxic material and the appearance of a resultant health effect.

Lead (Pb): a heavy metal. Several isotopes of lead, such as Pb-210 which emits beta radiation, are in the uranium decay chain.

Lead Federal Agency (LFA): the federal agency that leads and coordinates the emergency response activities of other federal agencies during a nuclear emergency. After a nuclear emergency, the Federal Radiological Emergency Response Plan (FRERP, available at http://www.fas.org/nuke/guide/usa/doctrine/national/frerp.htm) will determine which federal agency will be the LFA.

Local radiation injury (LRI): acute radiation exposure (more than 1,000 rads) to a small, localized part of the body. Most local radiation injuries do not cause death. However, if the exposure is from penetrating radiation (neutrons, x-rays, or gamma rays), internal organs may be damaged and some symptoms of acute radiation syndrome (ARS), including death, may occur. Local radiation injury invariably involves skin damage, and a skin graft or other surgery may be required. *See also CDC's fact sheet "Acute Radiation Syndrome" at* http://www.bt.cdc.gov/radiation/ars.asp.

Low-level waste (LLW): radioactively contaminated industrial or research waste such as paper, rags, plastic bags, medical waste, and water-treatment residues. It is waste that does not meet the criteria for any of three other categories of radioactive waste: spent nuclear fuel and high-level radioactive waste; transuranic radioactive waste; or uranium mill tailings. Its categorization does not depend on the level of radioactivity it contains.

Megaton (Mt): the energy of an explosion that is equivalent to an explosion of 1 million tons of TNT. One megaton is equal to a quintillion (10^{18}) calories. *See also* kiloton.

Molecule: a combination of two or more atoms that are chemically bonded. A molecule is the smallest unit of a compound that can exist by itself and retain all of its chemical properties.

Neoplastic: pertaining to the pathologic process resulting in the formation and growth of an abnormal mass of tissue.

Neutron: a small atomic particle possessing no electrical charge typically found within an atom's nucleus. Neutrons are, as the name implies, neutral in their charge. That is, they have neither a positive nor a negative charge. A neutron has about the same mass as a proton. *See also* alpha particle, beta particle, gamma ray, nucleon, x-ray.

Non-ionizing radiation: radiation that has lower energy levels and longer wavelengths than ionizing radiation. It is not strong enough to affect the structure of atoms it contacts but is strong enough to heat tissue and can cause harmful biological effects. Examples include radio waves, microwaves, visible light, and infrared from a heat lamp.

Non-stochastic effects: effects that can be related directly to the radiation dose received. The effect is more severe with a higher does. It typically has a threshold, below which the effect will not occur. These are sometimes called deterministic effects. For example, a skin burn from radiation is a non-stochastic effect that worsens as the radiation dose increases. *See also* stochastic effects.

Nuclear energy: the heat energy produced by the process of nuclear fission within a nuclear reactor or by radioactive decay.

Nuclear fuel cycle: the steps involved in supplying fuel for nuclear power plants. It can include mining, milling, isotopic enrichment, fabrication of fuel elements, use in reactors, chemical reprocessing to recover the fissile material remaining in the spent fuel, reenrichment of the fuel material refabrication into new fuel elements, and waste disposal.

Nuclear tracers: radioisotopes that give doctors the ability to "look" inside the body and observe soft tissues and organs, in a manner similar to the way x-rays provide images of bones. A radioactive tracer is chemically attached to a compound that will concentrate naturally in an organ or tissue so that an image can be taken.

Nucleon: a proton or a neutron; a constituent of the nucleus of an atom.

Nucleus: the central part of an atom that contains protons and neutrons. The nucleus is the heaviest part of the atom.

Nuclide: a general term applicable to all atomic forms of an element. Nuclides are characterized by the number of protons and neutrons in the nucleus, as well as by the amount of energy contained within the atom.

Pathways: the routes by which people are exposed to radiation or other contaminants. The three basic pathways are inhalation, ingestion, and direct external exposure. *See also* exposure pathway.

Penetrating radiation: radiation that can penetrate the skin and reach internal organs and tissues. Photons (gamma rays and x-rays), neutrons, and protons are penetrating radiations. However, alpha particles and all but extremely high-energy beta particles are not considered penetrating radiation.

Photon: discrete "packet" of pure electromagnetic energy. Photons have no mass and travel at the speed of light. The term "photon" was developed to describe energy when it acts like a particle (causing interactions at the molecular or atomic level), rather than a wave. Gamma rays and x-rays are photons.

Pitchblende: a brown to black mineral that has a distinctive luster. It consists mainly of urananite (UO_2), but also contains radium (Ra). It is the main source of uranium (U) ore.

Plume: the material spreading from a particular source and traveling through environmental media, such as air or ground water. For example, a plume could describe the dispersal of particles, gases, vapors, and aerosols in the atmosphere, or the movement of contamination through an aquifer (For example, dilution, mixing, or adsorption onto soil).

Plutonium (Pu): a heavy, man-made, radioactive metallic element. The most important isotope is Pu-239, which has a half-life of 24,000 years. Pu-239 can be used in reactor fuel and is the primary isotope in weapons. One kilogram is equivalent to about 22 million kilowatt-hours of heat energy. The complete detonation of a kilogram of plutonium produces an explosion equal to about 20,000 tons of chemical explosive. All isotopes of plutonium are readily absorbed by the bones and can be lethal depending on the dose and exposure time.

Polonium (Po): a radioactive chemical element and a product of radium (Ra) decay. Polonium is found in uranium (U) ores.

Prenatal radiation exposure: radiation exposure to an embryo or fetus while it is still in its mother's womb. At certain stages of the pregnancy, the fetus is particularly sensitive to radiation and the health consequences could be severe above 5 rads, especially to brain function. *For more information, see CDC's fact sheet,* "Possible Health Effects of Radiation Exposure on Unborn Babies," *at* http://www.bt.cdc.gov/radiation/prenatal.asp.

Protective Action Guide (PAG): a guide that tells state and local authorities at what projected dose they should take action to protect people from exposure to unplanned releases of radioactive material into the environment.

Proton: a small atomic particle, typically found within an atom's nucleus, that possesses a positive electrical charge. Even though protons and neutrons are about 2,000 times heavier than electrons, they are tiny. The number of protons is unique for each chemical element. *See also* nucleon.

Quality factor (Q): the factor by which the absorbed dose (rad or gray) is multiplied to obtain a quantity that expresses, on a common scale for all ionizing radiation, the biological damage (rem) to an exposed person. It is used because some types of radiation, such as alpha particles, are more biologically damaging internally than other types. *For more information, see* "Primer on Radiation Measurement" *at the end of this document*.

Rad (radiation absorbed dose): a basic unit of absorbed radiation dose. It is a measure of the amount of energy absorbed by the body. The rad is the traditional unit of absorbed dose. It is being replaced by the unit gray (Gy), which is equivalent to 100 rad. One rad equals the dose delivered to an object of 100 ergs of energy per gram of material. *For more information, see* "Primer on Radiation Measurement" *at the end of this document*.

Radiation: energy moving in the form of particles or waves. Familiar radiations are heat, light, radio waves, and microwaves. Ionizing radiation is a very high-energy form of electromagnetic radiation.

Radiation sickness: *See also* acute radiation syndrome (ARS), *or the CDC fact sheet* "Acute Radiation Syndrome," *at* http://www.bt.cdc.gov/radiation/ars.asp.

Radiation warning symbol: a symbol prescribed by the Code of Federal Regulations. It is a magenta or black trefoil on a yellow background. It must be displayed where certain quantities of radioactive materials are present or where certain doses of radiation could be received.

Radioactive contamination: the deposition of unwanted radioactive material on the surfaces of structures, areas, objects, or people. It can be airborne, external, or internal. *See also* contamination, decontamination.

Radioactive decay: the spontaneous disintegration of the nucleus of an atom.

Radioactive half-life: the time required for a quantity of a radioisotope to decay by half. For example, because the half-life of iodine-131 (I-131) is 8 days, a sample of I-131 that has 10 mCi of activity on January 1, will have 5 mCi of activity 8 days later, on January 9. *See also:* biological half-life, decay constant, effective half-life.

Radioactive material: material that contains unstable (radioactive) atoms that give off radiation as they decay.

Radioactivity: the process of spontaneous transformation of the nucleus, generally with the emission of alpha or beta particles often accompanied by gamma rays. This process is referred to as decay or disintegration of an atom.

Radioassay: a test to determine the amounts of radioactive materials through the detection of ionizing radiation. Radioassays will detect transuranic nuclides, uranium, fission and activation products, naturally occurring radioactive material, and medical isotopes.

Radiogenic: health effects caused by exposure to ionizing radiation.

Radiography: 1) *medical:* the use of radiant energy (such as x-rays and gamma rays) to image body systems. 2) *industrial:* the use of radioactive sources to photograph internal structures, such as turbine blades in jet engines. A sealed radiation source, usually iridium-192 (Ir-192) or cobalt-60 (Co-60), beams gamma rays at the object to be checked. Gamma rays passing through flaws in the metal or incomplete welds strike special photographic film (radiographic film) on the opposite side.

Radioisotope (radioactive isotope): isotopes of an element that have an unstable nucleus. Radioactive isotopes are commonly used in science, industry, and medicine. The nucleus eventually reaches a stable number of protons and neutrons through one or more radioactive decays. Approximately 3,700 natural and artificial radioisotopes have been identified.

Radiological or radiologic: related to radioactive materials or radiation. The radiological sciences focus on the measurement and effects of radiation.

Radiological dispersal device (RDD): a device that disperses radioactive material by conventional explosive or other mechanical means, such as a spray. *See also* dirty bomb.

Radionuclide: an unstable and therefore radioactive form of a nuclide.

Radium (Ra): a naturally occurring radioactive metal. Radium is a radionuclide formed by the decay of uranium (U) and thorium (Th) in the environment. It occurs at low levels in virtually all rock, soil, water, plants, and animals. Radon (Rn) is a decay product of radium.

Radon (Rn): a naturally occurring radioactive gas found in soils, rock, and water throughout the United States. Radon causes lung cancer and is a threat to health because it tends to collect in homes, sometimes to very high concentrations. As a result, radon is the largest source of exposure to people from naturally occurring radiation.

Relative risk: the ratio between the risk for disease in an irradiated population to the risk in an unexposed population. A relative risk of 1.1 indicates a 10% increase in cancer from radiation, compared with the "normal" incidence. *See also* risk, absolute risk.

Rem (roentgen equivalent, man): a unit of equivalent dose. Not all radiation has the same biological effect, even for the same amount of absorbed dose. Rem relates the absorbed dose in human tissue to the effective biological damage of the radiation. It is determined by multiplying the number of rads by the quality factor, a number reflecting the potential damage caused by the particular type of radiation. The rem is the traditional unit of equivalent dose, but it is being replaced by the sievert (Sv), which is equal to 100 rem. *For more information, see* "Primer on Radiation Measurement" *at the end of this document*.

Risk: the probability of injury, disease, or death under specific circumstances and time periods. Risk can be expressed as a value that ranges from 0% (no injury or harm will occur) to 100% (harm or injury will definitely occur). Risk can be influenced by several factors: personal behavior or lifestyle, environmental exposure to other material, or inborn or inherited characteristic known from scientific evidence to be associated with a health effect. Because many risk factors are not exactly measurable, risk estimates are uncertain. *See also* absolute risk, relative risk.

Risk assessment: an evaluation of the risk to human health or the environment by hazards. Risk assessments can look at either existing hazards or potential hazards.

Roentgen (R): a unit of exposure to x-rays or gamma rays. One roentgen is the amount of gamma or x-rays needed to produce ions carrying 1 electrostatic unit of electrical charge in 1 cubic centimeter of dry air under standard conditions.

Sensitivity: ability of an analytical method to detect small concentrations of radioactive material.

Shielding: the material between a radiation source and a potentially exposed person that reduces exposure.

Sievert (Sv): a unit used to derive a quantity called dose equivalent. This relates the absorbed dose in human tissue to the effective biological damage of the radiation. Not all radiation has the same biological effect, even for the same amount of absorbed dose. Dose equivalent is often expressed as millionths of a sievert, or micro-sieverts (µSv). One sievert is equivalent to 100 rem. *For more information, see* "Primer on Radiation Measurement" *at the end of this document*.

S.I. units: the Systeme Internationale (or International System) of units and measurements. This system of units officially came into being in October 1960 and has been adopted by nearly all countries, although the amount of actual usage varies considerably. *For more information, see* "Primer on Radiation Measurement" *at the end of this document*.

Somatic effects: effects of radiation that are limited to the exposed person, as distinguished from genetic effects, which may also affect subsequent generations. *See also* teratogenic effects.

Stable nucleus: the nucleus of an atom in which the forces among its particles are balanced. *See also* unstable nucleus.

Stochastic effect: effect that occurs on a random basis independent of the size of dose. The effect typically has no threshold and is based on probabilities, with the chances of seeing the effect increasing with dose. If it occurs, the severity of a stochastic effect is independent of the dose received. Cancer is a stochastic effect. *See also* non-stochastic effect, deterministic effect.

Strontium (Sr): a silvery, soft metal that rapidly turns yellow in air. Sr-90 is one of the radioactive fission materials created within a nuclear reactor during its operation. Stronium-90 emits beta particles during radioactive decay.

Surface burst: a nuclear weapon explosion that is close enough to the ground for the radius of the fireball to vaporize surface material. Fallout from a surface burst contains very high levels of radioactivity. *See also* air burst. *For more information, see Chapter 2 of CDC's Fallout Report at* http://www.cdc.gov/nceh/radiation/fallout/falloutreport.pdf .

Tailings: waste rock from mining operations that contains concentrations of mineral ore that are too low to make typical extraction methods economical.

Thermonuclear device: a "hydrogen bomb." A device with explosive energy that comes from fusion of small nuclei, as well as fission.

Teratogenic effect: birth defects that are not passed on to future generations, caused by exposure to a toxin as a fetus. *See also* genetic effects, somatic effects.

Terrestrial radiation: radiation emitted by naturally occurring radioactive materials, such as uranium (U), thorium (Th), and radon (Rn) in the earth.

Thorium (Th): a naturally occurring radioactive metal found in small amounts in soil, rocks, water, plants, and animals. The most common isotopes of thorium are thorium-232 (Th-232), thorium-230 (Th-230), and thorium-238 (Th-238).

Transuranic: pertaining to elements with atomic numbers higher than uranium (92). For example, plutonium (Pu) and americium (Am) are transuranics.

Tritium: (chemical symbol H-3) a radioactive isotope of the element hydrogen (chemical symbol H). *See also* deuterium.

Unstable nucleus: a nucleus that contains an uneven number of protons and neutrons and seeks to reach equilibrium between them through radioactive decay (i.e., the nucleus of a radioactive atom). *See also* stable nucleus.

UNSCEAR: United Nations Scientific Committee on the Effects of Atomic Radiation. *See also* http://www.unscear.org/.

Uranium (U): a naturally occurring radioactive element whose principal isotopes are uranium-238 (U-238) and uranium-235 (U-235). Natural uranium is a hard, silvery-white, shiny metallic ore that contains a minute amount of uranium-234 (U-234).

Uranium mill tailings: naturally radioactive residue from the processing of uranium ore. Although the milling process recovers about 95% of the uranium, the residues, or tailings, contain several isotopes of naturally occurring radioactive material, including uranium (U), thorium (Th), radium (Ra), polonium (Po), and radon (Rn).

Whole body count: the measure and analysis of the radiation being emitted from a person's entire body, detected by a counter external to the body.

Whole body exposure: an exposure of the body to radiation, in which the entire body, rather than an isolated part, is irradiated by an external source.

X-ray: electromagnetic radiation caused by deflection of electrons from their original paths, or inner orbital electrons that change their orbital levels around the atomic nucleus. X-rays, like gamma rays can travel long distances through air and most other materials. Like gamma rays, x-rays require more shielding to reduce their intensity than do beta or alpha particles. X-rays and gamma rays differ primarily in their origin: x-rays originate in the electronic shell; gamma rays originate in the nucleus. *See also* neutron.

Primer on Radiation Measurement

In the aftermath of a radiological emergency the public will see radiation and its potential hazards described in many different and sometimes confusing ways. This primer is intended to help journalists and community leaders understand these terms.

Activity or radioactivity is measured by the number of atoms disintegrating per unit time. A ***becquerel*** is 1 disintegration per second. A ***curie*** is 37 billion disintegrations per second, which is the number of disintegrations per second in 1 gram of pure radium. A disintegrating atom can emit a beta particle, an alpha particle, a gamma ray, or some combination of all these, so becquerels or curies alone do not provide enough information to assess the risk to a person from a radioactive source.

Disintegrating atoms emit different forms of radiation—–alpha particles, beta particles, gamma rays, or x-rays. As radiation moves through the body, it dislodges electrons from atoms, disrupting molecules. Each time this happens, the radiation loses some energy until it escapes from the body or disappears. The energy deposited indicates the number of molecules disrupted. The energy the radiation deposits in tissue is called the ***dose***, or more correctly, the ***absorbed dose***. The units of measure for absorbed dose are the ***gray*** (1 joule per kilogram of tissue) or the ***rad*** (1/100 of a gray*)*. The ***cumulative dose*** is the total absorbed dose or energy deposited by the body or a region of the body from repeated or prolonged exposures.

Alpha particles, beta particles, gamma rays, and x-rays affect tissue in different ways. Alpha particles disrupt more molecules in a shorter distance than gamma rays. A measure of the biologic risk of the energy deposited is the ***dose equivalent***. The units of dose equivalent are ***sieverts*** or ***rem***. Dose equivalent is calculated by multiplying the absorbed dose by a ***quality factor***.

Sometimes a large number of people have been exposed to a source of ionizing radiation. To assess the potential health effects, scientists often multiply the exposure per person by the number of persons and call this the ***collective dose***. Collective dose is expressed as “person-rem” or “person-sieverts.”

Abbreviations for Radiation Measurements

When the amounts of radiation being measured are less than 1, prefixes are attached to the unit of measure as a type of shorthand. This is called scientific notation and is used in many scientific fields. The table below shows the prefixes for radiation measurement and their associated numeric notations.

Prefix	Equal to	How Much Is That?	Abbreviation	Example
atto-	1×10^{-18}	.000000000000000001	A	aCi
femto-	1×10^{-15}	.000000000000001	F	fCi
pico-	1×10^{-12}	.000000000001	p	pCi
nano-	1×10^{-9}	.000000001	n	nCi
micro-	1×10^{-6}	.000001	μ	μCi
milli-	1×10^{-3}	.001	m	mCi
centi-	1×10^{-2}	.01	c	cSv

When the amount to be measured is 1,000 (i.e., 1 X 10^3) or higher, prefixes are attached to the unit of measure to shorten very large numbers (also scientific notation). The table below shows the prefixes used in radiation measurement and their associated numeric notations.

Prefix	Equal to	How Much Is That?	Abbreviation	Example
kilo-	1 X 10^3	1,000	k	kCi
mega-	1 X 10^6	1,000,000	M	MCi
giga-	1 X 10^9	1,000,000,000	G	GBq
tera-	1 X 10^{12}	1,000,000,000,000	T	TBq
peta-	1 X 10^{15}	1,000,000,000,000,000	P	PBq
exa-	1 x 10^{18}	1,000,000,000,000,000,000	E	EBq

Health Effects of Radiation Exposure
Exposure to radiation can cause two kinds of health effects. ***Deterministic effects*** are observable health effects that occur soon after receipt of large doses. These may include hair loss, skin burns, nausea, or death. ***Stochastic effects*** are long-term effects, such as cancer. The radiation dose determines the severity of a deterministic effect and the probability of a stochastic effect.

The object of any radiation control program is to prevent any deterministic effects and minimize the risk for stochastic effects. When a person inhales or ingests a radionuclide, the body will absorb different amounts of that radionuclide in different organs, so each organ will receive a different ***organ dose***. Federal Guidance Report 11 (FGR-11) from the Environmental Protection Agency (EPA) lists ***dose conversion factors*** for all radionuclides. This report can be downloaded from http://www.epa.gov/radiation/pubs.htm. The dose conversion factor for each organ is the number of rem delivered to that organ by each curie or becquerel of intake of a specific radioisotope.

External, Internal, and Absorbed Doses
A person can receive an ***external dose*** by standing near a gamma or high-energy beta-emitting source. A person can receive an ***internal dose*** by ingesting or inhaling radioactive material. The external exposure stops when the person leaves the area of the source. The internal exposure continues until the radioactive material is flushed from the body by natural processes or decays.

A person who has ingested a radioactive material receives an internal dose to several different organs. The absorbed dose to each organ is different, and the sensitivity of each organ to radiation is different. FGR-11 assigns a different weighting factor to each organ. To determine a person's risk for cancer, multiply each organ's dose by its weighting factor, and add the results; the sum is the ***effective dose equivalent*** ("effective" because it is not really the dose to the whole body, but a sum of the relative risks to each organ; and "equivalent" because it is presented in rem or sieverts instead of rads or gray).

Committed and Total Effective Dose Equivalents
When a person inhales or ingests a radionuclide, that radionuclide is distributed to different organs and stays there for days, months, or years until it decays or is excreted. The radionuclide will deliver a radiation dose over a period of time. The dose that a person receives from the time the nuclide enters the body until it is gone is the ***committed dose***. FGR-11 calculates doses over a 50-year period and presents the ***committed dose equivalent*** for each organ plus the ***committed effective dose equivalent*** (CEDE).

A person can receive both an internal dose and an external dose. The sum of the committed effective dose equivalent (CEDE) and the external dose is called the ***total effective dose equivalent*** (TEDE).

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