ANNUAL SITE ENVIRONMENTAL REPORT
Helpful Information

WHAT IS RADIATION?

A significant portion of the Annual Site Environmental Report focuses on radioactivity levels measured in environmental media such as air, water, soil, and plants. To assist individuals with limited or no familiarity with radiological data or radiation dose, a guide was developed. This guide explains the terminology and concepts used in the Annual Site Environmental Report to help the reader understand the information.

Matter is composed of atoms. Some atoms are energetically unstable and change to become more stable. During this transformation, unstable or radioactive atoms give off energy called radiation in the form of particles or electromagnetic waves. Generally, we refer to the various radioactive atoms as radionuclides. The radiation released by radionuclides has enough energy to eject electrons from other atoms it encounters. The resulting charged atoms or molecules are called ions, and the energetic radiation that produced the ions is called ionizing radiation. Ionizing radiation is referred to simply as radiation throughout the Annual Site Environmental Report. The most common types of radiation are alpha particles, beta particles, X-rays, and gamma-rays. X-rays and gamma-rays, just like visible light and radio waves, are packets of electromagnetic radiation. Collectively, packets of electromagnetic radiation are called photons. One may, for instance, speak of X-ray photons or gamma-ray photons.

Alpha Particles

An alpha particle is a helium nucleus without orbital electrons. It is composed of two protons and two neutrons and has a positive charge of two. Because alpha particles are relatively heavy and have a double charge, they cause intense tracks of ionization but have little penetrating ability, as observed in Figure 1. Alpha particles can be stopped by thin layers of materials, such as a sheet of paper or a piece of aluminum foil. Examples of alpha-emitting radionuclides include radioactive atoms of radon, uranium, plutonium, and americium.

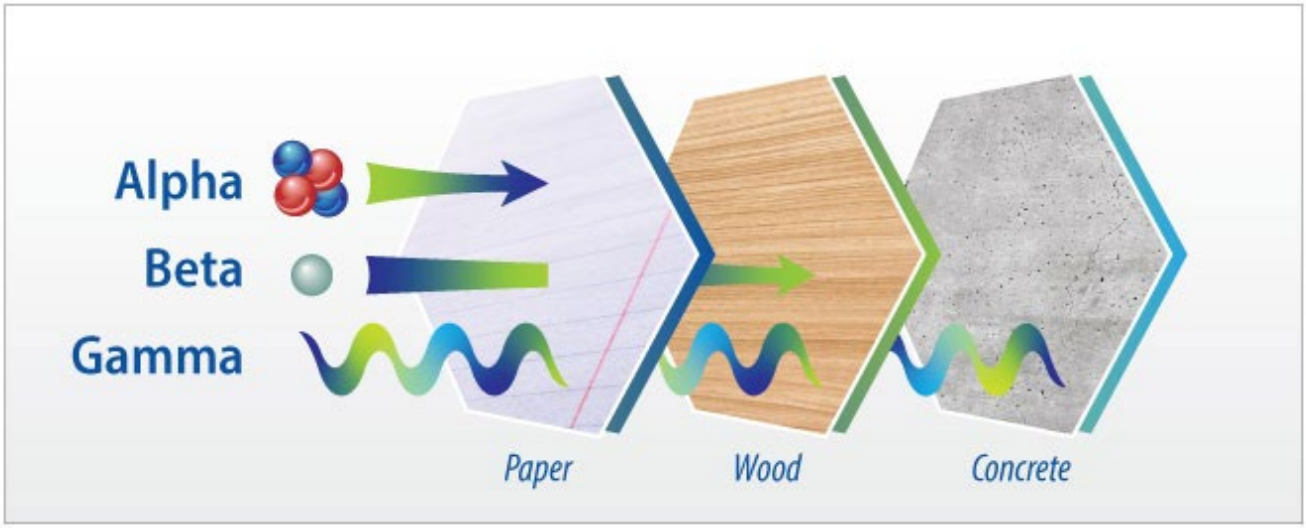

Figure 1. Comparison of penetrating ability of alpha, beta, and gamma radiation.

Beta Particles

Beta particles are electrons that are ejected from unstable atoms during the transformation or decay process. Beta particles penetrate more than alpha particles but are less penetrating than X-rays or gamma-rays of equivalent energies. A piece of wood or a thin block of plastic can stop beta particles, as

can be seen in Figure 1. The ability of beta particles to penetrate matter increases with energy. Examples of beta-emitting radionuclides include tritium (^{3}H) and radioactive strontium.

X-Rays and Gamma-Rays

X-rays and gamma-rays are photons with very short wave-lengths compared to other electromagnetic waves such as visible light, heat rays, and radio waves. Gamma-rays and X-rays have identical properties, behavior, and effects but differ in their origin. Gamma-rays originate from an atomic nucleus, and X-rays originate from interactions with the electrons orbiting around atoms. All photons travel at the speed of light. Their energies, however, vary over a large range. The penetration of X-ray or gamma-ray photons depends on the energy of the photons, as well as the thickness, density, and composition of the shielding material. Concrete is a common material used to shield people from gamma-rays and X-rays, as shown in Figure 1.

Examples of gamma-emitting radionuclides include radioactive atoms of iodine and cesium. X-rays may be produced by medical X-ray machines in a doctor's office.

HOW ARE RADIONUCLIDES DESIGNATED?

Radionuclides are frequently expressed with a one or two letter abbreviation for the element and a superscript to the left of the symbol that identifies the atomic weight of the isotope. The atomic weight is the number of protons and neutrons in the nucleus of the atom. Most radionuclide symbols used in the Annual Site Environmental Report are shown in Table 1. This table also shows the half-life of each radionuclide. Half-life refers to the time in which one-half of the atoms of a radioactive sample transform or decay in the quest to achieve a more energetically stable nucleus. Most radionuclides do not decay directly to a stable element but rather undergo a series of decays until a stable element is reached. This series of decays is called a decay chain. Radiation dose is not delivered unless a decay event occurs.

HOW ARE RADIOACTIVITY AND RADIONUCLIDES DETECTED?

Environmental samples of air, water, soil, and plants are collected in the field and then prepared and analyzed for radioactivity in a laboratory. A prepared sample is placed in a radiation-counting system with a detector that converts the ionization produced by the radiation into electrical signals or pulses. The number of electrical pulses recorded over a unit of time is called a count rate. The count rate is proportional to the amount of radioactivity in the sample.

Air and water samples are often analyzed to determine the total amount of alpha-emitting and beta-emitting radioactivity present. This is referred to as a gross measurement because the radiation from all alpha-emitting and beta-emitting radionuclides in the sample is quantified. Such sample analyses measure both human-generated and naturally occurring radioactive material. Gross alpha and beta analyses are generally considered screening measurements since specific radionuclides are not identified. The amount of gross alpha-emitting and beta-emitting radioactivity in air samples is frequently measured to screen for the potential presence of man-made radionuclides. If the results are higher than normal, sources other than background radionuclides may be suspected, and other laboratory techniques may be used to identify the specific radionuclides in the sample. Gross alpha and beta activity also can be examined over time and between locations to detect trends.

The low penetration ability of alpha-emitting particles makes detection by any instrument difficult. Identifying specific alpha-emitting radionuclides typically involves chemical separations in the laboratory to purify the sample prior to analysis with an alpha detection instrument. Radiochemical analysis is very time-consuming and expensive.

Beta particles are easily detected by several types of instruments, including the common Geiger-Mueller counter. However, detection of specific beta-emitting radionuclides, such as ^{3}H and ^{90}Sr, requires chemical separation first.

Table 1. Radionuclides and their half-lives.

SYMBOL	RADIONUCLIDE	HALF-LIFE[a,b]	SYMBOL	RADIONUCLIDE	HALF-LIFE[a,b]
^{241}Am	Americium-241	432.2 yr	^{54}Mn	Manganese-54	312.12 d
^{243}Am	Americium-243	7,370 yr	^{59}Ni	Nickel-59	1.01×10^{5} yr
^{125}Sb	Antimony-125	2.75856 yr	^{63}Ni	Nickel-63	100.1 yr
^{41}Ar	Argon-41	109.61 min	^{238}Pu	Plutonium-238	87.7 yr
^{137m}Ba	Barium-137m	2.552 min	^{239}Pu	Plutonium-239	2.411×10^{4} yr
^{140}Ba	Barium-140	12.752 d	^{240}Pu	Plutonium-240	6,564 yr
^{7}Be	Beryllium-7	53.22 d	^{241}Pu	Plutonium-241	14.35 yr
^{14}C	Carbon-14	5,700 yr	^{242}Pu	Plutonium-242	3.75×10^{5} yr
^{141}Ce	Cerium-141	32.508 d	^{40}K	Potassium-40	1.251×10^{9} yr
^{144}Ce	Cerium-144	284.91 d	^{226}Ra	Radium-226	1,600 yr
^{134}Cs	Cesium-134	2.0648 yr	^{228}Ra	Radium-228	5.75 yr
^{137}Cs	Cesium-137	30.1671 yr	^{220}Rn	Radon-220	55.6 s
^{36}Cl	Chlorine-36	3.01×10^{5} yr	^{222}Rn	Radon-222	3.8235 d
^{51}Cr	Chromium-51	27.7025 d	^{103}Ru	Ruthenium-103	39.26 d
^{60}Co	Cobalt-60	5.2713 yr	^{106}Ru	Ruthenium-106	373.59 d
^{152}Eu	Europium-152	13.537 yr	^{90}Sr	Strontium-90	28.79 yr
^{154}Eu	Europium-154	8.593 yr	^{99}Tc	Technetium-99	2.111×10^{5} yr
^{3}H	Tritium	12.32 yr	^{232}Th	Thorium-232	1.405×10^{10} yr
^{129}I	Iodine-129	1.57×10^{7} yr	^{233}U	Uranium-233	1.592×10^{5} yr
^{131}I	Iodine-131	8.0207 d	^{234}U	Uranium-234	2.455×10^{5} yr
^{55}Fe	Iron-55	2.737 yr	^{235}U	Uranium-235	7.04×10^{8} yr
^{59}Fe	Iron-59	44.495 d	^{238}U	Uranium-238	4.468×10^{9} yr
^{85}Kr	Krypton-85	10.756 yr	^{90}Y	Yttrium-90	64.1 hr
^{87}Kr	Krypton-87	76.3 min	^{65}Zn	Zinc-65	244.06 d
^{88}Kr	Krypton-88	2.84 hr	^{95}Zr	Zirconium-95	64.032 d
^{212}Pb	Lead-212	10.64 hr			

a. From International Commission on Radiation Protection Publication 107 (ICRP 2008).
b. d = days; hr = hours; min = minutes; s = seconds; yr = years.

The high-energy photons from gamma-emitting radionuclides are relatively easy to detect. Because the photons from each gamma-emitting radionuclide have a characteristic energy, gamma emitters can be simply identified in the laboratory with only minimal sample preparation prior to analysis. Gamma-emitting radionuclides, such as ^{137}Cs, can even be measured in soil using an in-situ gamma detection system.

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Gamma radiation originating from naturally occurring radionuclides in soil and rocks on the earth's surface is a primary contributor to the background external radiation exposure measured in the air. Cosmic radiation from outer space is another contributor to the external radiation background. External radiation is easily measured with devices known as environmental dosimeters.

HOW ARE RESULTS REPORTED?

Scientific Notation

Concentrations of radionuclides detected in the environment are typically quite small. Scientific notation is used to express numbers that are very small or very large. A very small number may be expressed with a negative exponent, for example, 1.3×10^{-6} (or 1.3E-06). To convert this number to its decimal form, the decimal point is moved left by the number of places equal to the exponent (in this case, six). The number 1.3×10^{-6} may also be expressed as 0.0000013. When considering large numbers with a positive exponent, such as 1.3×10^{6}, the decimal point is moved to the right by the number of places equal to the exponent. In this case, 1.3×10^{6} represents one million three hundred thousand and may also be written as 1,300,000.

Unit Prefixes

Units for very small and very large numbers are often expressed with a prefix. One common example is the prefix kilo (abbreviated k), which means 1,000 of a given unit. One kilometer, therefore, equals 1,000 meters. Table 2 defines the values of commonly used prefixes.

Table 2. Multiples of units.

MULTIPLE	DECIMAL EQUIVALENT	PREFIX	SYMBOL
10^{6}	1,000,000	mega-	M
10^{3}	1,000	kilo-	k
10^{2}	100	hecto-	h
10	10	deka-	da
10^{-1}	0.1	deci-	d
10^{-2}	0.01	centi-	c
10^{-3}	0.001	milli-	m
10^{-6}	0.000001	micro-	μ
10^{-9}	0.000000001	nano-	n
10^{-12}	0.000000000001	pico-	p
10^{-15}	0.000000000000001	femto-	f
10^{-18}	0.000000000000000001	atto-	a

Units of Radioactivity

The basic unit of radioactivity used in the Annual Site Environmental Report is the curie (abbreviated Ci), which is based on 37 billion (3.7×10^{10}) disintegrations per second (becquerels). For any other radionuclide, 1 Ci is the amount of the radionuclide that produces this same decay rate.

Units of Exposure and Dose

Exposure, or the amount of ionization produced by gamma or X-ray radiation in the air, is measured in terms of the roentgen (R). Dose is a general term to express how much radiation energy is deposited into something. The energy deposited can be expressed in terms of absorbed, equivalent, and effective dose. The term rad, which is short for radiation absorbed dose, is a measure of the energy absorbed in an

organ or tissue. The equivalent dose, which considers the effect of different types of radiation on tissues and is therefore the potential for biological effects, is expressed as the R equivalent man or rem. Radiation exposures to the human body, whether from external or internal sources, can involve all or a portion of the body. To enable radiation protection specialists to express partial-body exposures (and the accompanying doses) to portions of the body in terms of an equal dose to the whole body, the concept of effective dose was developed. Table 3 lists the units of exposure and dose.

Table 3. Names and symbols for units of radioactivity and radiological dose used in the Annual Site Environmental Report.

SYMBOL	NAME
Bq	Becquerel
Ci	Curie (37,000,000,000 Bq)
mCi	Millicurie (1×10^{-3} Ci)
µCi	Microcurie (1×10^{-6} Ci)
mrad	Millirad (1×10^{-3} rad)
mrem	Millirem (1×10^{-3} rem)
R	Roentgen
mR	Milliroentgen (1×10^{-3} R)
µR	Microroentgen (1×10^{-6} R)
Sv	Sievert (100 rem)
mSv	Millisievert (100 mrem)
µSv	Microsievert (0.1 mrem)

The Système International (SI) is the official system of measurement used internationally to express units of radioactivity and radiation dose. The basic SI unit of radioactivity is the Becquerel (Bq), which is equivalent to one nuclear disintegration per second. The number of curies must be multiplied by 3.7×10^{10} to obtain the equivalent number of becquerels. The concept of dose may also be expressed using the SI units, Gray (Gy) for absorbed dose (1 Gy = 100 rad) and sievert (Sv) for effective dose (1 Sv = 100 rem).

Concentrations of Radioactivity in Environmental Sample Media

Table 4 shows the units used to identify the concentration of radioactivity in various sample media. There is always uncertainty associated with the measurement of radioactivity in environmental samples. This is mainly because radioactive decay events are inherently random. Thus, when a radioactive sample is counted again and again for the same length of time, the results will differ slightly, but most of the results will be close to the true value of the activity of the radioactive material in the sample. Statistical methods are used to estimate the true value of a single measurement and the associated uncertainty of the measurement. The uncertainty of a measurement is reported by following the result with an uncertainty value that is preceded by the plus or minus symbol, ± (e.g., 10 ± 2 pCi/L). The uncertainty is often referred to as sigma (or σ). For concentrations of greater than or equal to three times the uncertainty, there is 99% probability that the radionuclide was detected in a sample. For example, if a radionuclide is reported for a sample at a concentration of 10 ± 2 pCi/L, then the radionuclide is considered to be detected in that sample because 10 is greater than 3 × 2, or 6. On the other hand, if the reported concentration of a radionuclide (e.g., 10 ± 6 pCi/L) is smaller than three times its associated uncertainty, then the sample probably does not contain that radionuclide (i.e., 10 is less than 3 × 6, or 18). Such low concentrations are considered to be undetected by the method or instrumentation used.

Table 4. Units of radioactivity.

MEDIA	UNIT
Air	Microcuries per milliliter (µCi/mL)
Liquid, such as water and milk	Picocuries per liter (pCi/L)
Soil and agricultural products	Picocuries per kilogram (pCi/kg) dry weight
Annual human radiation exposure, measured by environmental dosimeters	Milliroentgens (mR) or millirem (mrem), after being multiplied by an appropriate dose equivalent conversion factor

Mean, Median, Maximum, and Minimum Values

Descriptive statistics are often used to express the patterns and distribution of a group of results. The most common descriptive statistics used in the Annual Site Environmental Report are the mean, median, minimum, and maximum values. Mean and median values measure the central tendency of the data. The mean is calculated by adding up all the values in a set of data and then dividing that sum by the number of values in the dataset. The median is the middle value in a group of measurements. When the data are arranged from largest (maximum) to smallest (minimum), the result in the exact center of an odd number of results is the median. If there is an even number of results, the median is the average of the two central values. The maximum and minimum results represent the range of measurements.

Statistical analysis of many of the air data reported in the Annual Site Environmental Report indicates that the median is a more appropriate representation of the central tendency of those results. For this reason, some of the figures present the median value of a data group. For example, Figure 2 is a box plot showing the minimum, maximum, and median of a set of air measurements.

HOW ARE DATA REPRESENTED GRAPHICALLY?

Charts and graphs often are used to compare data and to visualize patterns, such as trends over time. Four kinds of graphics are used in the Annual Site Environmental Report to represent data: pie charts, column graphs, line plots, and contour lines.

A ***pie chart*** is used in the Annual Site Environmental Report to illustrate fractions of a whole. For example, Figure 3 shows the percent contribution, by facility, to the maximally exposed individual from Idaho National Laboratory Site airborne effluents. The maximally exposed individual is a hypothetical member of the public who is exposed to radionuclides from airborne releases through various environmental pathways and the media through which the radionuclides are transported (i.e. air, water, and food).

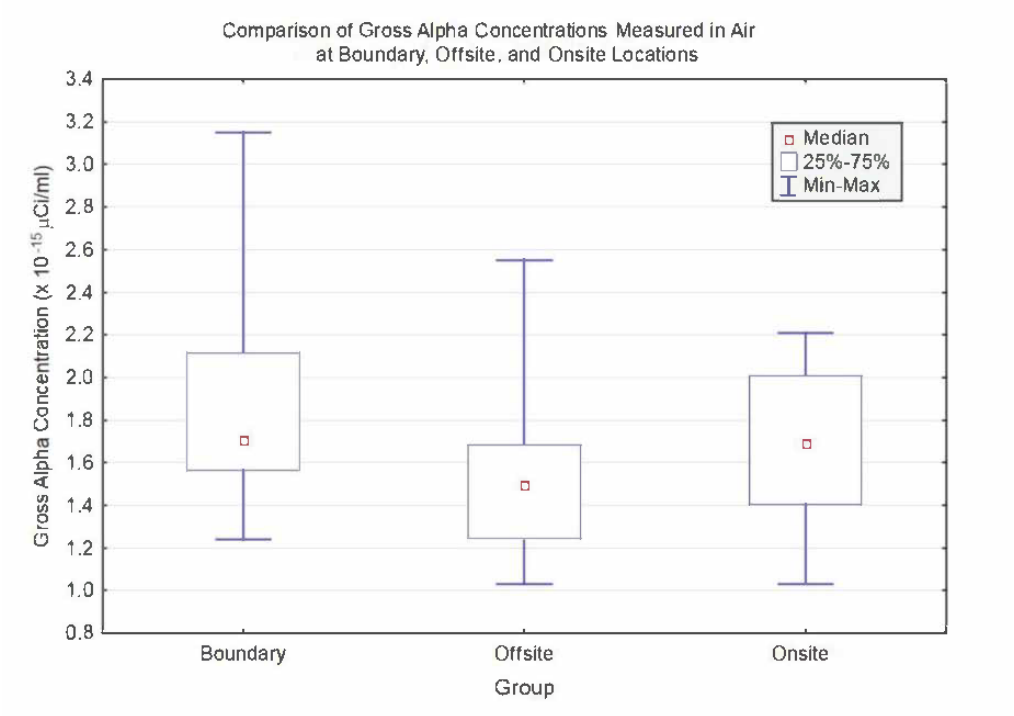

Figure 2. A graphical representation of minimum, median, and maximum results with a box plot. The 25th and 75th percentiles are the values such that 75% of the measurements in the dataset are greater than the 25th percentile, and 75% of the measurements are less than the 75th percentile.

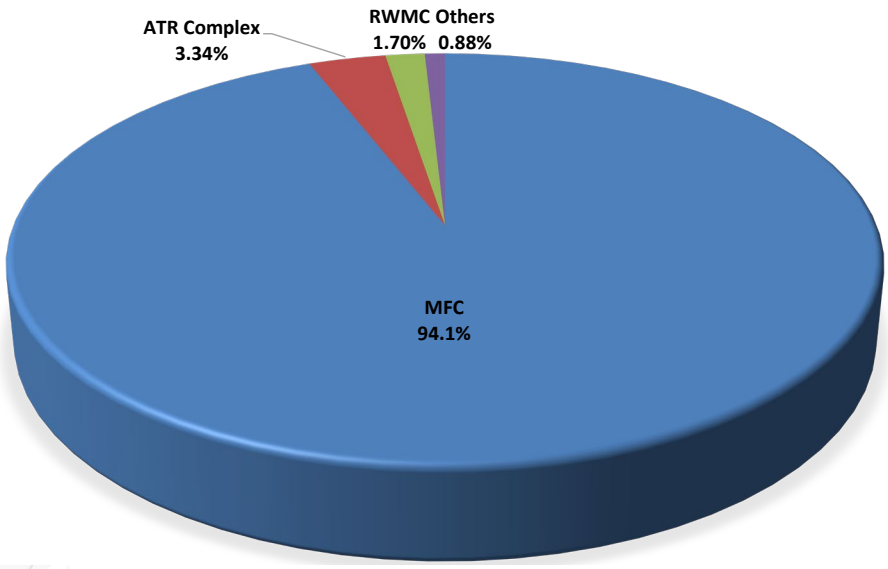

Figure 3. Data presented using a pie chart.

A ***column or bar chart*** can show data changes over a period of time or illustrate comparisons among items. Figure 4 illustrates the maximum dose (mrem) calculated for the maximally exposed individual from 2015 through 2024. The chart shows the general trend of the dose over time.

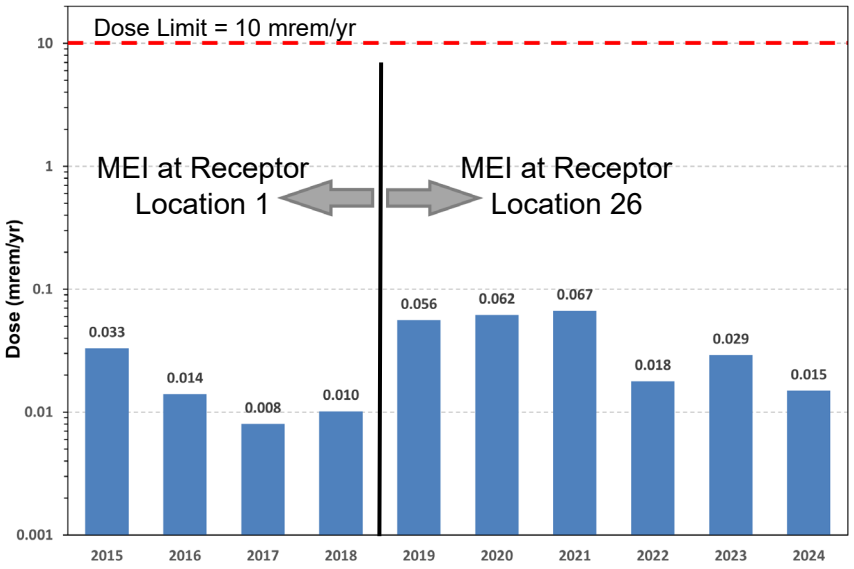

Figure 4. Data plotted using a column chart.

A ***plot chart*** can be useful to visualize differences in results over time. Figure 5 shows the ^{90}Sr measurements in three wells collected by United States Geological Survey for 21 years (2003–2023). The results are plotted by year.

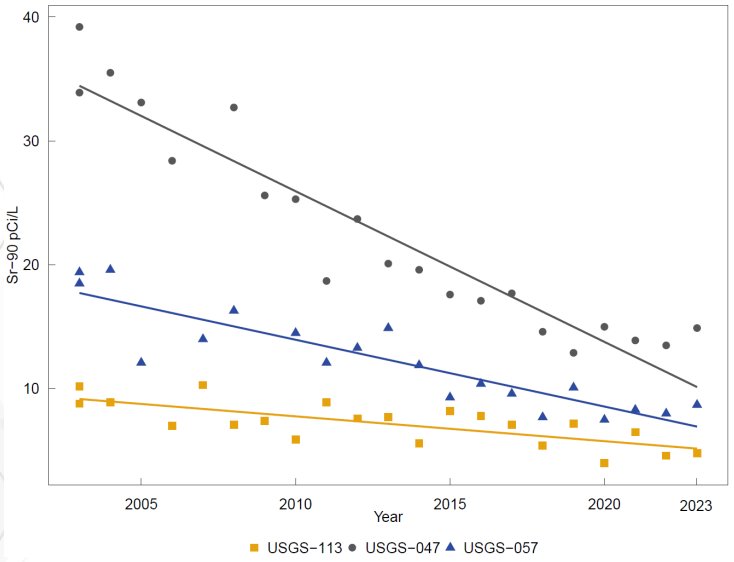

Figure 5. Data plotted using a linear plot.

Contour lines are sometimes drawn on a map to discern patterns over a geographical area. For example, Figure 6 shows the distribution of ^{90}Sr in groundwater around Idaho Nuclear Technology and Engineering Center (INTEC). Each contour line, or isopleth, represents a specific concentration of the radionuclide in groundwater. It was estimated from measurements of samples collected from wells around INTEC. Each contour line separates areas that have concentrations above the contour line value from those that have concentrations below that value. The figure shows the highest concentration gradient near INTEC and the lowest farther away. It reflects the movement of the radionuclide in groundwater from INTEC where it was injected into the aquifer in the past.

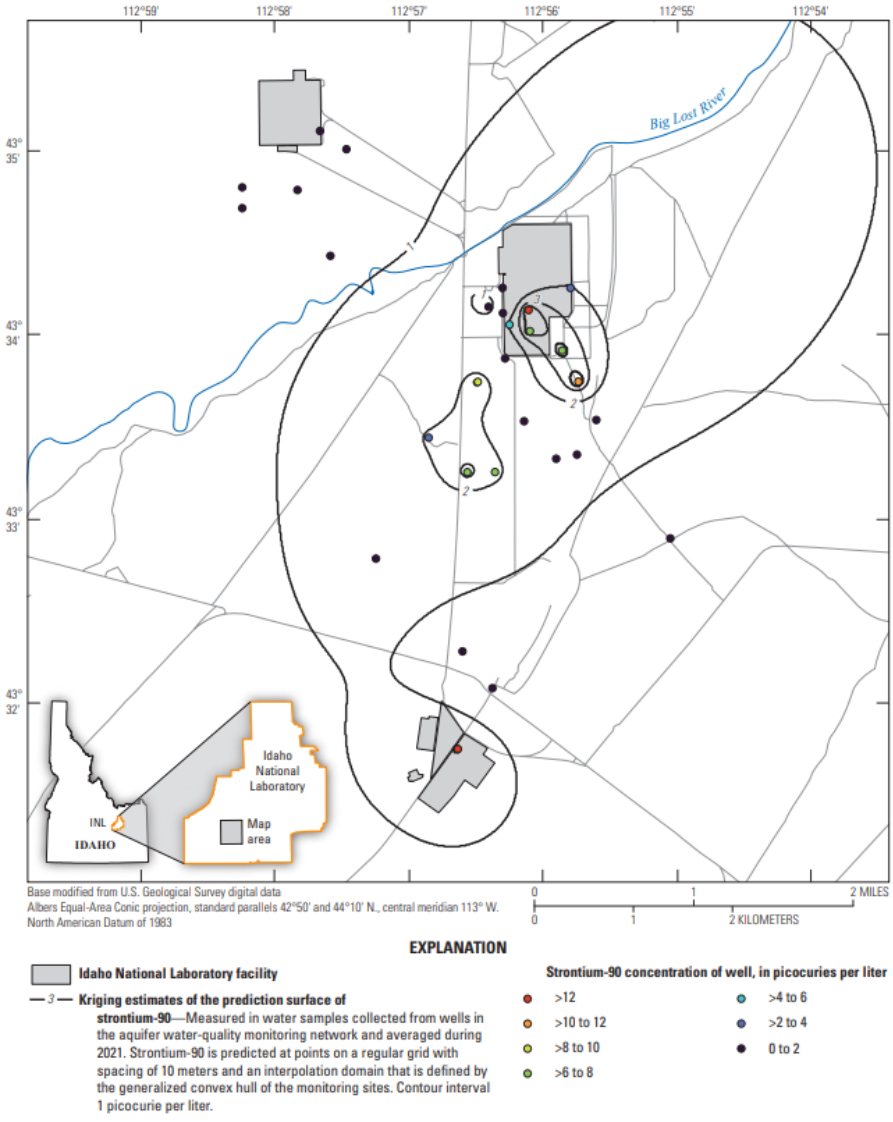

Figure 6. Data plotted using contour lines. Each contour line drawn on this map connects points of equal ^{90}Sr concentration in water samples collected at the same depth from wells onsite.

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HOW ARE RESULTS INTERPRETED?

To better understand data, results are compared in one or more ways, including the following:

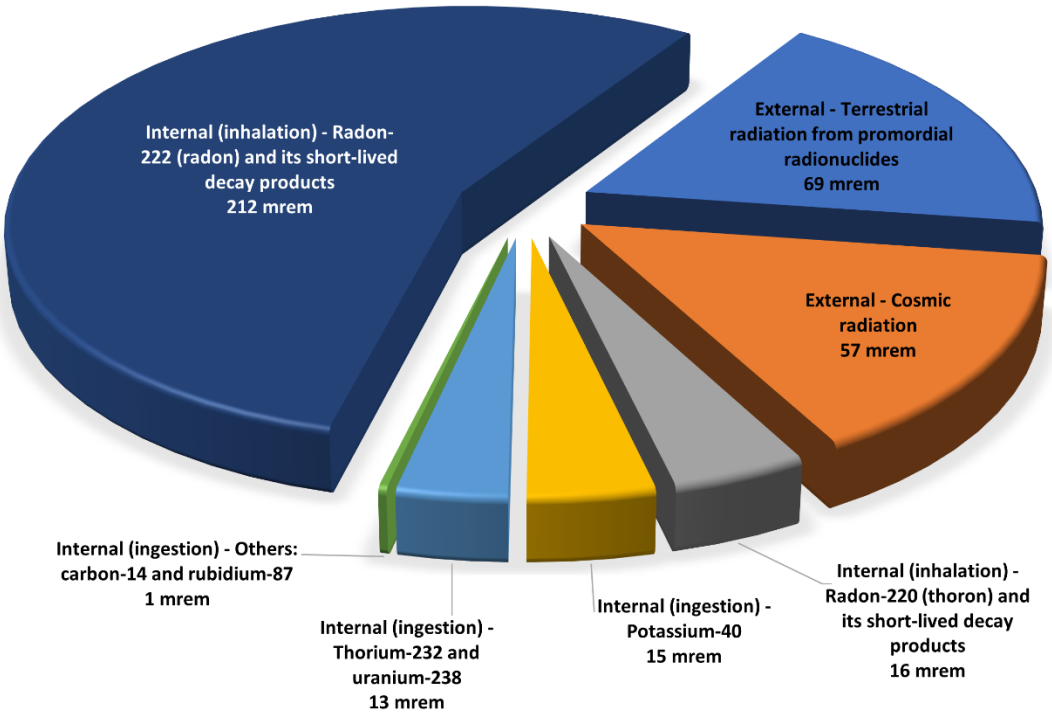
- Comparison of results collected at different locations. For example, measurements made at onsite locations are compared with those made at locations near the boundary of the INL Site and offsite to find differences that may indicate an impact (Figure 2).
- Trends over time or space. Data collected during the year can be compared with data collected at the same location or locations during previous years to see if concentrations are increasing, decreasing, or remaining the same with time. See, for example, Figure 4, which shows a general decrease in dose from 2014 to 2018, followed by a slight increase in 2019. Figure 6 illustrates a clear spatial pattern of radionuclide concentrations in groundwater decreasing with distance from the source.
- Comparison with background measurements. Humans are now, and always have been, continuously exposed to ionizing radiation from natural background sources. Background sources include natural radiation and radioactivity, as well as radionuclides from human activities. These sources are discussed in the following section.

WHAT IS BACKGROUND RADIATION?

Radioactivity from natural and fallout sources is detectable as background in all environmental media. Natural sources of radiation include: (1) radiation of extraterrestrial origin (called cosmic rays), (2) radionuclides produced in the atmosphere by cosmic ray interaction with matter (called cosmogenic radionuclides), and (3) radionuclides present at the time of the formation of the earth (called primordial radionuclides). Radiation that has resulted from the activities of modern man is primarily fallout from past atmospheric testing of nuclear weapons. One of the challenges of environmental monitoring on and around the INL Site is to distinguish between what may have been released from the INL Site and what is already present in background from natural and fallout sources. These sources are discussed in more detail below.

Natural radiation and radioactivity in the environment, which is natural background, represent a major source of human radiation exposure (NCRP 1987, 2009). For this reason, natural radiation frequently is used as a standard of comparison for exposure to various human-generated sources of ionizing radiation. An individual living in southeast Idaho was estimated to receive an average dose (2020-2024) of about 383 mrem/yr (3.8 mSv/yr) from natural background sources of radiation on earth, as observed in Figure 7. These sources include cosmic radiation and naturally occurring radionuclides. The average listed here does not include dose from medical procedures or consumer products.

Cosmic radiation is radiation that constantly bathes the earth in extraterrestrial sources. The atmosphere around the earth absorbs some of the cosmic radiation, so doses are lowest at sea level and increase sharply with altitude. Cosmic radiation is estimated using data in NCRP (2009) to produce a dose of about 57 mrem/yr (0.57 mSv/yr) to a typical individual living in southeast Idaho (Figure 7). Cosmic radiation also produces cosmogenic radionuclides, which are found naturally in all environmental media and are discussed in more detail below.



Five year average (2020-2024) = 383 mrem

Figure 7. Calculated doses (mrem per year) from natural background sources for an average individual living in southeast Idaho.

Naturally occurring radionuclides are of two general kinds: cosmogenic and primordial. Cosmogenic radionuclides are produced by the interaction of cosmic radiation within the atmosphere or in the earth. Cosmic rays have high enough energies to blast apart atoms in the earth's atmosphere. The result is the continuous production of radionuclides, such as ^{3}H, beryllium-7 (^{7}Be), sodium-22 (^{22}Na), and ^{14}C. Cosmogenic radionuclides, particularly ^{3}H and ^{14}C, have been measured in humans, animals, plants, soil, polar ice, surface rocks, sediments, the ocean floor, and the atmosphere. Concentrations are generally higher at mid-latitudes than at low- or high-latitudes. Cosmogenic radionuclides contribute only about 1 mrem/yr to the total average dose, mostly from ^{14}C, that might be received by an adult living in the U.S. (NCRP 2009). Tritium and ^{7}Be are routinely detected in environmental samples collected by environmental monitoring programs on and around the INL Site, as observed in Table 5, but these contribute little to the dose that might be received from natural background sources.

Primordial radionuclides are those that were present when the earth was formed. The primordial radionuclides detected today are billions of years old. The radiation dose to a person from primordial radionuclides comes from internally deposited radioactivity, inhaled radioactivity, and external radioactivity in soils and building materials. Three of the primordial radionuclides—potassium-40 (^{40}K), uranium-238 (^{238}U), and thorium-232 (^{232}Th)—are responsible for most of the dose received by people from natural background radioactivity. They have been detected in environmental samples collected on and around the INL Site (Table 5). The external dose to an adult living in southeast Idaho from terrestrial natural background radiation exposure has been estimated using concentrations of ^{40}K, ^{238}U, and ^{232}Th

measured in soil samples collected from areas surrounding the INL Site from 1976 through 1993. The average external dose to an adult from terrestrial natural background radiation over the last five years (2020-2024) is approximately 69 mrem/yr or 0.69mSv/yr. This external dose varies slightly from year to year based on the amount of snow cover. Amounts of ^{238}U and ^{232}Th are also estimated to contribute 13 mrem/yr (0.13 mSv/yr) to an average adult through ingestion (NCRP 2009).

Table 5. Naturally occurring radionuclides that have been detected in environmental media collected on and around the INL Site.

RADIONUCLIDE	HALF-LIFE	HOW PRODUCED?	DETECTED OR MEASURED IN:
Beryllium-7 (^{7}Be)	53.22 days	Cosmic rays	Rain, air
Potassium-40 (^{40}K)	1.2516×10^{9} yr	Primordial	Water, air, soil, plants, animals
Radium-226 (^{226}Ra)	1,600 yr	^{238}U progeny	Water
Thorium-232 (^{232}Th)	1.405×10^{10} yr	Primordial	Soil
Tritium (^{3}H)	12.32 yr	Cosmic rays	Water, rain, air moisture
Uranium-234 (^{234}U)	2.455×10^{5} yr	^{238}U progeny	Water, air, soil
Uranium-238 (^{238}U)	4.468×10^{9} yr	Primordial	Water, air, soil

Potassium-40 is abundant and measured in living and non-living matter. It is found in human tissue and is a significant source of internal dose to the human body (approximately 15 mrem/yr [0.15 mSv/yr] according to NCRP [2009]). Rubidium-87 (^{87}Rb), another primordial radionuclide, contributes a small amount (< 1 mrem/yr) to the internal dose received by people but is not typically measured in onsite samples.

Uranium-238 and ^{232}Th initiate a decay chain of radionuclides. A radioactive decay chain starts with one type of radioactive atom called the parent that decays and changes into another type of radioactive atom called a progeny radionuclide. This system repeats, involving several different radionuclides. The parent radionuclide of the uranium decay chain is ^{238}U. The most familiar element in the uranium series is radon, specifically radon-222 (^{222}Rn). This is a gas that can accumulate in buildings. Radon and its progeny are responsible for most of the inhalation dose (e.g., an average of 200 mrem/yr [2.0 mSv/yr] nationwide) produced by naturally occurring radionuclides, as shown in Figure 7.

The parent radionuclide of the thorium series is ^{232}Th. Another isotope of radon, called thoron, occurs in the thorium decay chain of radioactive atoms. Amounts of ^{238}U, ^{232}Th, and their progeny are often detected in environmental samples (Table 5).

Global Fallout

The U.S., the Union of Soviet Socialist Republics, and China tested nuclear weapons in the earth's atmosphere in the 1950s and 1960s. This testing resulted in the release of radionuclides into the upper atmosphere, and such a release is referred to as fallout from weapons testing. Concerns over worldwide fallout rates eventually led to the Partial Test Ban Treaty in 1963, which limited signatories to underground testing. Not all countries stopped atmospheric testing with the treaty. France continued atmospheric testing until 1974, and China continued until 1980. Additional fallout, but to a substantially smaller extent, was produced by the Chernobyl and Fukushima nuclear accidents in 1986 and 2011, respectively.

Most of the radionuclides associated with nuclear weapons testing and the Chernobyl and Fukushima accidents have decayed and are no longer detected in environmental samples. Radionuclides that are currently detected in the environment and typically associated with global fallout include ^{90}Sr and ^{137}Cs. Strontium-90, a beta-emitter with a 29-year half-life, is important because it is chemically similar to

calcium and tends to accumulate in bone tissues. Cesium-137, which has a 30-year half-life, is chemically similar to potassium and accumulates rather uniformly in muscle tissue throughout the body.

The deposition of these radionuclides on the earth's surface varies by latitude, with most occurring in the northern hemisphere at approximately 40 degrees. Variation within latitudinal belts is a function primarily of precipitation, topography, and wind patterns. The dose produced by global fallout from nuclear weapons testing has decreased steadily since 1970. The annual dose rate from fallout was estimated in 1987 to be less than 1 mrem (0.01 mSv) (NCRP 1987). It has been nearly 34 years since that estimate, so the current dose is assumed to be even lower.

WHAT ARE THE RISKS OF EXPOSURE TO LOW LEVELS OF RADIATION?

Radiation protection standards for the public have been established by state and federal agencies based mainly on recommendations of the National Council on Radiation Protection and Measurements. The National Council on Radiation Protection and Measurements was chartered by Congress to provide recommendations in the public interest based on scientific data. Through radiation protection standards, exposure to members of the public is controlled so that risks are small enough to be considered insignificant compared to the risks undertaken during other activities deemed normal and acceptable in modern life.

A large amount of data exists concerning the effects of acute delivery (dose delivered all at once) for high doses of radiation. Most of this information was gathered from the Japanese atomic bombing survivors, medical exposures (both diagnostic and therapeutic exposures, industrial exposures, and high natural background studies). Decades ago, the dataset used to estimate risk for high doses was extrapolated to lower doses using a Linear No Threshold (LNT) risk model. The LNT model *assumes* that for any dose, there is an effect. LNT was an easy-to-use regulatory tool designed to provide conservative recommendations in the absence of data. Current epidemiological studies have failed to demonstrate validity of LNT or show statistically significant health effects at doses below 10,000 mrem when doses are delivered at low dose rates (small doses delivered over long periods of time, as would be the case with public exposures). The Health Physics Society even states that "below 10,000 mrem (including occupational and environmental exposures), risks of health effects are either too small to be observed or are nonexistent."

DOE limits the dose to a member of the public from all sources and pathways to 100 mrem (1 mSv) and the dose from the air pathway to 10 mrem (0.1 mSv) (DOE NE O 458.1A). The doses estimated to maximally exposed individuals from INL Site releases are typically well below 1 mrem per year, or 1% of the legal limit. The risk to the public from INL Site operations is significantly lower than that from a dental X-ray. Over the past ten years (2015 – 2024), the highest estimated dose for the maximally exposed individual was 0.067 mrem, which is much lower than the 0.4 mrem dose from a dental X-ray.

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