Health Physics Society
Specialists in Radiation Safety

Fact Sheet
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Uranium[1]

What is uranium?

Uranium is a naturally occurring metallic element that has been present in the Earth's crust since formation of the planet. Like many other minerals, uranium was deposited on land by volcanic action, dissolved by rainfall, and in some places, carried into underground formations. In some cases, geochemical conditions resulted in its concentration into "ore bodies." Uranium is a common element in Earth's crust (soil, rock) and in seawater and groundwater.

Uranium has 92 protons in its nucleus. The *isotope*[2] ^{238}U has 146 neutrons, for a total atomic weight of approximately 238, making it the highest atomic weight of any naturally occurring element. It is not the most dense of elements, but its density is almost twice that of lead.

Uranium is radioactive and in nature has three primary isotopes with different numbers of neutrons. Natural uranium, ^{238}U, constitutes over 99% of the total mass or weight, with 0.72% ^{235}U, and a very small amount of ^{234}U.

An unstable nucleus that emits some form of radiation is defined as radioactive. The emitted radiation is called radioactivity, which in this case is ionizing radiation—meaning it can interact with other atoms to create charged atoms known as ions. Uranium emits *alpha particles*, which are ejected from the nucleus of the unstable uranium atom. When an atom emits radiation such as alpha or *beta particles* or photons such as *x rays* or *gamma rays*, the material is said to be undergoing *radioactive decay* (also called radioactive transformation). Eventually, all radioactive atoms will decay into nonradioactive atoms. Uranium eventually becomes nonradioactive lead. Each new radionuclide in the decay chain is called a decay product or *progeny*. Depending on the radionuclide, each uranium progeny radionuclide will emit an alpha particle or a beta particle, usually accompanied by gamma and x rays. Typically, the radioactivity of the uranium progeny contributes about seven times more to the total radioactivity of uranium in the soil than that of the uranium itself.

The *half-life* is the time that it takes for one-half of the atoms of a radionuclide to decay. The abundance and half-life of each uranium isotope determines its contribution to the radioactivity of natural uranium. Table 1 lists the relative mass (weight), half-life, and radioactivity of the three naturally occurring isotopes of uranium (US DHHS 2013).

Table 1. Constituents of natural uranium

Isotope	% Mass	Half-life (years)	% Radioactivity
^{238}U	99.3	4.5 billion	48.9
^{235}U	0.72	704 million	2.2
^{234}U	0.005	245,000	48.9

[1] Adapted from "A Citizen's Guide to Uranium" (Brown 2009)

[2] Words in italics are defined in the Glossary.

How much uranium is in our environment?

Uranium in soil

The mass concentration of uranium in soil varies widely, but is typically about 3 parts per million (ppm), or 0.07 *becquerels* per gram (Bq g^{-1}). A becquerel is a very small amount of radioactivity equal to one decay per second. A square kilometer of earth, 30 cm deep, will typically contain a ton or more of uranium. In the United States today, the concentration of radioactivity in uranium ore bodies is on average about 0.3% by weight, or about 78 Bq g^{-1}.

Uranium in groundwater

The average concentration of uranium in the groundwater of the United States is about 0.07 Bq L^{-1}. The US Environmental Protection Agency's (EPA) drinking-water standard for uranium is 30 micrograms per liter (µg L^{-1}), which is about 0.75 Bq L^{-1} (US EPA 2001).

Uranium concentrations can vary considerably from place to place depending on local geology and other factors. Numerous studies conducted in the United States indicate that uranium levels in groundwater used for domestic purposes, including drinking water, are sometimes many times higher than the EPA's drinking-water standard.

Uranium in food

Typical annual uranium intakes from a few example foods include (Welford 1967):

- Whole-grain products: 0.3 Bq y^{-1}.
- Fruit: about 1–2 Bq y^{-1}.
- Meat: about 2–3 Bq y^{-1}.

The radiation to which we are exposed from sources like soil, water, and food is referred to as background radiation. *Radon*, a decay product of uranium, is one of the largest contributors to our background radiation (NCRP 1989). Radon is a gas that escapes from the ground. We are exposed to various concentrations of radon depending on a number of factors, including the amount of uranium in the soil.

The variability of uranium concentration in soil across the United States and parts of Canada in parts per million of equivalent uranium (ppm eU) is illustrated in Fig. 1. Equivalent uranium means that the amount of uranium isotopes that were actually detected were adjusted to account for the other uranium isotopes (i.e., all of the uranium present is included). One ppm eU is equal to about 0.025 Bq g^{-1} (US NRC 1992). The US Geological Survey (USGS 2009) has compiled other aerial radiation survey data to illustrate the variability in annual background exposure based on where one chooses to live, eat, and drink.

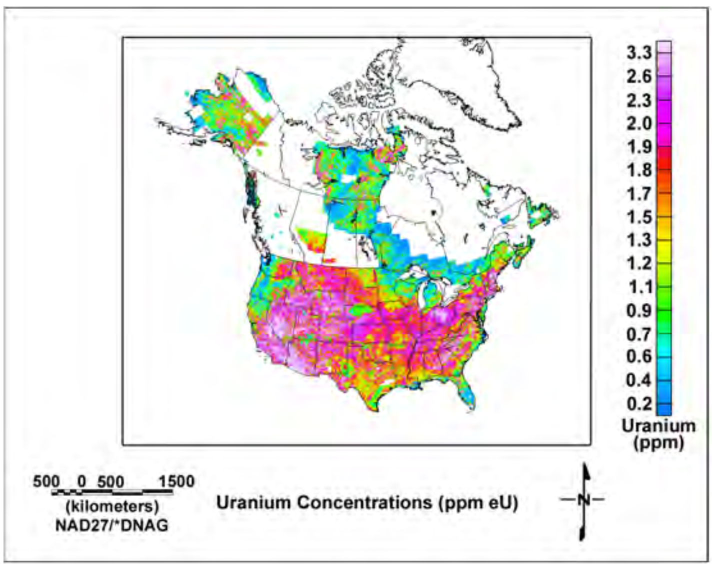

Fig. 1: Uranium concentration in soil in the United States (USGS 2009)

For what is uranium used?

Uranium is primarily used as fuel for electrical generation in nuclear reactors. Approximately 20% of US electricity is generated by uranium fuel in nuclear power plants (99 plants in the United States, over 400 currently worldwide). In addition to electricity production, nuclear reactors are used to generate radioactive material needed for radiopharmaceuticals used extensively in medicine for diagnosis and treatment of various diseases.

The uranium used in nuclear reactors typically has been enriched, meaning it has been processed to increase the abundance of ^{235}U from the natural level of less than 1 percent to around 4 percent. The other leftover isotopes of uranium that remain after most of the ^{235}U has been extracted is referred to as depleted uranium (DU). DU is an extremely dense and heavy metal, but it is relatively malleable and is used in military armor and armament as well as counterweights on ships and aircraft (HPS 2010b). Uranium was used for many years as a coloring agent in ceramics and glass (HPS 2010a).

What are the potential health effects from uranium?

Uranium is a heavy metal and acts similarly to other heavy metals in the body, such as molybdenum, lead, or mercury (Kathren and Burklin 2008). Because of its relatively long half-life, uranium exposure standards are usually based on its potential for chemical toxicity, not on its radioactivity (US NRC 1992; Brown and Chambers 2014). The Health Physics Society (HPS) DU fact sheet (HPS 2010b) states: “In general, natural uranium and DU are considered to be a chemical hazard to the kidney instead of a radiation hazard. Therefore, inhalation and/or ingestion of these materials should be minimized.” Despite the prevalence of uranium production and use in the United States, there has never been a documented death or permanent injury to a human from uranium poisoning. Additionally, possible health effects in populations living near uranium mines, mills, and nuclear power plants have been well studied. “No human cancer of any type has ever been seen as a result of exposure to natural or depleted uranium” (ATSDR 2013).

Although some might question these conclusions, the vast majority of scientists agree with them. The information presented here represents “consensus science,” that is, the generally agreed-upon positions of national and international bodies of experts, many of whom are appointed to these positions by their peers or by their governments from around the world.

Glossary

This fact sheet may use terms that are unfamiliar. Many of these are denoted in italics in the text and are defined in this glossary. More can be found on the Radiation Terms and Definitions page on the HPS website.

Alpha Particles
Positively charged particles consisting of two neutrons and two protons. Alpha particles are relatively large and easily stopped. A sheet of paper will stop alpha particles.

Beta Particles
Negatively charged, high-energy electrons that can be stopped by plastic.

Becquerel (Bq)
The international unit of measure of an amount of radioactivity. It is defined as the decay of one atom per second.

Gamma and X Rays
Electromagnetic radiation similar to light, radio, TV, and microwaves, but with higher energy. Thin lead for lower energies and thicker lead for higher-energy gamma or x rays is used for shielding.

Half-Life
The time it takes for one-half of the atoms of a radioactive nuclide to decay.
Isotope
An atom of an element with the same number of protons, but with different numbers of neutrons in the nucleus.

Progeny or decay products
The elements or isotopes into which a radionuclide transforms as it undergoes decay.

Radioactive Decay
The decrease in the amount of any radioactive material with the passage of time due to the spontaneous emission from the atomic nuclei of either alpha or beta particles, often accompanied by gamma radiation.

Radon
A naturally occurring radioactive gas that is released into the atmosphere at the earth's surface. Radon is a decay product of uranium.

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Resources for more information

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The Health Physics Society is a nonprofit scientific professional organization whose mission is excellence in the science and practice of radiation safety. Formed in 1956, the Society has approximately 3,500 scientists, physicians, engineers, lawyers, and other professionals. Activities include encouraging research in radiation science, developing standards, and disseminating radiation safety information. The Society may be contacted at 950 Herndon Parkway, Suite 450, Herndon, VA 20170; phone: 703-790-1745; fax: 703-790-2672; email: HPS@BurkInc.com.