Uranium Primer

What is it?
Where is it found?
What is it used for?

Contents

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Uranium in the natural environment

- “Primordial” element part of Earth’s formation 4.5 billion years ago (originated in supernovas)
- Deposited on land by volcanic action over geologic time
- Dissolved by rainfall and carried into underground formations
- Chemical conditions in some locations resulted in concentration into “ore bodies”

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Uranium in the natural environment

- Uranium decaying in Earth's core and mantle is major source of heat that drives geological and tectonic processes—convection, continental drift, etc.
- Fairly common element in Earth's crust (soil, rock) and in groundwater and seawater, typically 2-4 ppm[1] —as common as tin, tungsten, molybdenum, etc.
- A square mile of earth, one foot deep, will typically contain over a ton of uranium.
- Discovered in 1789 by Martin Klaproth, a German chemist, in the mineral pitchblende.

[1]ppm = parts per million

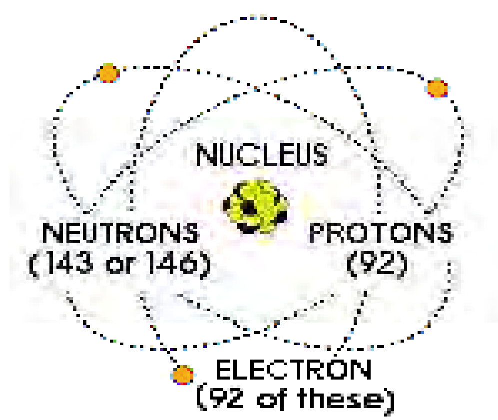
What is “natural uranium”?

- “Natural uranium” means uranium as it exists in nature as a combination of three different “isotopes.”
- Chemically, the isotopes are all uranium since they have 92 protons (p) in the center (nucleus) of their atoms but vary in the number of neutrons (n) in their nucleus (so have different masses).
- All uranium isotopes are radioactive and emit radiation.

$^{238}U = 146\ n + 92\ p$

$^{235}U = 143\ n + 92\ p$

$^{234}U = 142\ n + 92\ p$



The Three Isotopes in "Natural Uranium"

Isotope	Percent of Mass in Natural Uranium	Percent of Radioactivity in Natural Uranium	Half-Life (years)*
^{238}U	99.3	48.9	4.5 billion
^{235}U	0.72	2.2	704 million
^{234}U	0.005	48.9	245,000

Source: Agency for Toxic Substances and Disease Registry. Toxicological profile for uranium. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service; 1999. Available at: http://www.atsdr.cdc.gov/toxprofiles/tp150.html.

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* Time it takes 1/2 of atoms to decay, i.e., try to become stable by losing energy. For example, one pound of uranium at the time of Earth's formation would have decayed to 1/2 pound today.

How common are uranium and its daughter products[1] in nature?[2]

Typical concentration in soil and rocks (pCi*/gram):

- Uranium = 0.6-3.0
- Uranium in "phosphate rock" = 40-80
- Radium = 0.4-3.6
- Thorium = 0.2-2.2

Typical uranium concentration in water = 1-2 pCi/liter

[1]Daughter products = those chemical elements that uranium decays into as a result of its radioactive properties. Thorium and radium are also radioactive.

[2]Sources: (1) National Council on Radiation Protection and Measurements. Natural background radiation in the United States. Washington, DC: National Council on Radiation Protection and Measurements; NCRP Report No. 45; 1975. (2) National Council on Radiation Protection and Measurements. Exposure of the population in the United States and Canada from natural background radiation. Bethesda, MD: National Council on Radiation Protection and Measurements; NCRP Report No. 94; 1992 (updates and supersedes NCRP Report No. 45).

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[*]pCi = picocurie, one-trillionth of a curie, the amount of radioactivity where approximately two atoms decay per minute. Picocurie is a measure of the amount of radioactivity.

How much uranium is in the food and water we eat and drink?

Typical annual uranium intake in example foods:

- Whole-grain products: 10 pCi
- Meat: 50-70 pCi
- Fresh fruit: 30-51 pCi
- Potatoes: 67-74 pCi
- Bakery products: 39-44 pCi

Sources: (1) National Council on Radiation Protection and Measurements. Exposures from the uranium series with emphasis on radon and its daughters. Bethesda, MD: National Council on Radiation Protection and Measurements; NCRP Report No. 77; 1987. (2) Welford GA, Baird R. Uranium levels in human diet and biological materials. Health Phys 13(12):1,321-1,324, 1967 (values for three U.S. cities—New York City, Chicago, San Francisco).

How radioactive is uranium ore?

- Typical uranium ore contains 670 pCi/gram of uranium (assuming 1,000 ppm of uranium in the ore).
- Household smoke detector (americium) = average of 50,000,000 pCi[1].
- Household smoke detector (radium) = 50,000 pCi[1].
- Typical older (pre-1970) luminous wrist watch dials (radium) = up to 4,500,000 pCi[1].

[1]National Council on Radiation Protection and Measurements. Radiation exposure from consumer products and miscellaneous sources. Washington, DC: National Council on Radiation Protection and Measurements; NCRP Report No. 56; 1977.

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How radioactive is uranium ore?

- Typical modern luminous wrist watch dials: radioactive hydrogen (tritium) average of 1,300,000,000 and promethium average of 45,000,000 pCi[1]
- Coal fly ash (radium) = 1-2 pCi/gram[1]
- Additional consumer products containing naturally occurring radioactivity include fertilizers (uranium, thorium, potassium), gas lantern mantles (thorium), glass and ceramics (uranium as coloring agent)[2]

[1]National Council on Radiation Protection and Measurements. Radiation exposure from consumer products and miscellaneous sources. Washington, DC: National Council on Radiation Protection and Measurements; NCRP Report No. 56; 1977.

[2]Health Physics Society. Consumer products containing radioactive materials. Health Physics Society Fact Sheet. Available at: www.hps.org/hpspublications/radiationfactsheets.html. Accessed 14 August 2008.

Annual natural background radiation exposure compared to annual regulatory limits for uranium mines and mills

Table of Natural Background Radiation*

Source	U.S. Average[1]	Colorado Average[2]	Leadville[2]
Cosmic radiation (from space)	27	50	85
Terrestrial radiation (from the ground)	28	49	97
Inhaled naturally occurring radon and its decay products	200	301	344
TOTAL	255	400	526

*In units of mrem/y; mrem (millirem) is a unit of effective radiation dose. One rem is 1,000 mrem.

[1]National Council on Radiation Protection and Measurements. Exposure of the Population in the United States and Canada from Natural Background Radiation. Bethesda, MD: National Council on Radiation Protection and Measurements; NCRP Report No. 94; 1992.

[2] Moeller D, Sun LSC. Comparison of natural background dose rates for residents of the Amargosa Valley, NV, to those in Leadville, CO, and the states of Colorado and Nevada. Health Phys 91:338-353; 2006.

Annual natural background radiation exposure compared to annual regulatory limits for uranium mines and mills

- Background Levels (from previous slide)
  - Colorado average = 400 mrem
  - Leadville, Colorado = 526 mrem
  - U.S. average = 255 mrem

- Regulatory Limits
  - EPA drinking water standard = 4 mrem[1]
  - EPA limit for all exposure pathways = 25 mrem[2]

[1] U.S. Environmental Protection Agency. Radionuclides in drinking water. Available at: http://www.epa.gov/safewater/radionuclides/index.html. Accessed 14 August 2008.

[2] U.S. Environmental Protection Agency. Environmental radiation protection for nuclear power operations, 40 CFR 190.10; 2006.

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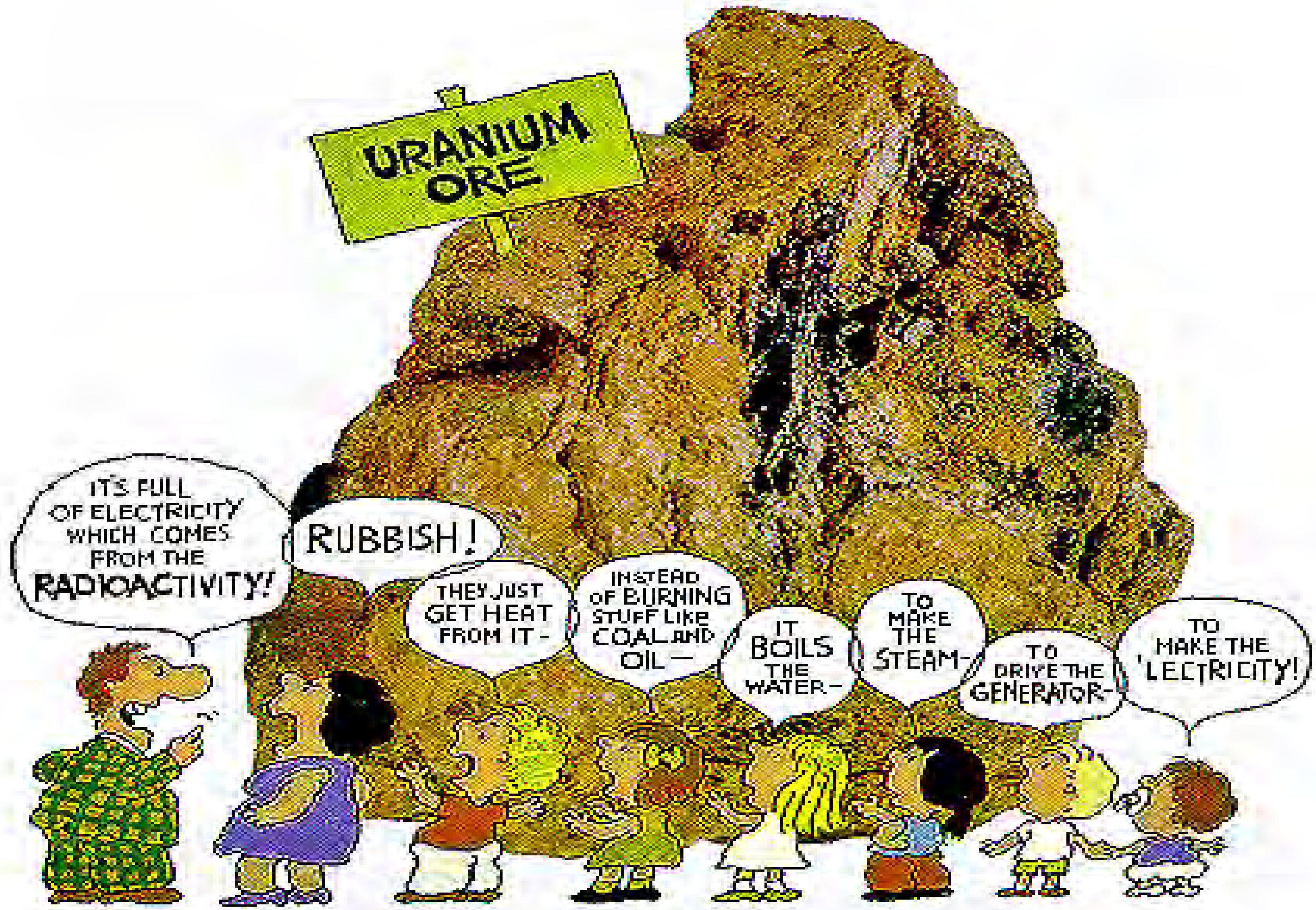
What are the potential health effects from exposure to uranium?[1]

- Uranium is a heavy metal and acts similar to lead (another heavy metal) in the body.
- Accordingly, for natural uranium, national and international human exposure standards are based on the possible **chemical toxicity** of uranium (e.g., effect on kidney—nephrotoxicity), not on radiation and possible "cancer effects" (radiotoxicity).

[1]Sources: (1) U.S. Nuclear Regulatory Commission. Standards for protection against radiation. Washington, DC: U.S. Government Printing Office; 10 CFR Part 20; 1992. (2) International Commission on Radiological Protection. Limits for intakes of radionuclides by workers. Oxford: Pergamon Press; ICRP Publication 30, Part 1; Ann ICRP 2(3/4); 1979. (3) Agency for Toxic Substances and Disease Registry. Toxicological profile for uranium. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service; 1999. Available at: http://www.atsdr.cdc.gov/toxprofiles/tp150.html. Accessed 14 August 2008.

What is uranium used for?



Courtesy of Australian Uranium Association at www.aua.org.au

What is uranium used for?

- Number-one use = Electricity generation via nuclear fission. Approximately 20 percent of U.S. electricity is generated by uranium fuel in nuclear power plants (over 400 plants currently world wide and many more planned).
- Uranium fission in nuclear reactors makes isotopes used in medicine (e.g., ^{99}Mo, which produces ^{99m}Tc for diagnostic imaging studies).

Nuclear fission—each "fission" of a ^{235}U atom by a neutron results in release of radiation (heat, light, gamma and x rays), more neutrons, and other particles.

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What is uranium used for?

- One 7-gram (1/4-ounce) uranium fuel pellet has an energy-to-electricity equivalent of 3.5 barrels of oil or 17,000 cubic feet of natural gas or 1,780 pounds of coal.

- Other uses include:
  - Coloring agent in ceramics and glass
  - Military armor and armament
  - Counterweights on ships and aircraft
  - Radiation shielding (extremely dense and heavy metal but relatively flexible)

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How does a conventional mine and mill recover uranium?

- Large volumes of rock and soil containing uranium ore are extracted from underground mines or open pits at/near the surface.

- The rock is crushed and the uranium is dissolved out of the crushed rock in the mill.

- Milling processes extract the uranium from solution and concentrate it into the final “yellowcake” (U_3O_8) product.

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How does an in situ recovery (ISR) process recover uranium?

- Natural geochemical processes brought uranium out of the groundwater millions of years ago, forming uranium roll-front deposits, which are now mined using the ISR process.
- ISR methods reverse the geochemical processes and make the uranium soluble in groundwater, forming a solution that is then pumped to a plant on the surface.
- Uranium is loaded on resin in closed metallic columns or tanks to concentrate it.
- It is then processed similarly to conventional uranium mills to produce the final "yellowcake" product.

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“Uranium Facts” to remember

- Uranium is a common element in the rock and soil of the Earth.
- It is contained in the food we eat, in the water we drink, and as dust in the air we breathe.
- The background radiation exposure we receive each year in the Rocky Mountain region can be several times higher than in other parts of the United States.

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“Uranium Facts” to remember

- The federal radiation exposure limits that control public exposure from uranium mines and mills are a small fraction of our natural background exposure and much less than the differences in natural background exposure across the United States.
- Potential health effects from inhaling or ingesting natural uranium are associated with its chemical properties (heavy metal), not radiation.
- At present, approximately 20 percent of U.S. electricity is generated using uranium-fueled nuclear power plants.

This material was prepared by the Central Rocky Mountain Chapter, Health Physics Society, and has been approved for distribution via the HPS Web site by current President Ken Weaver and President-elect Steve Brown.

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