# A Citizen's Guide To Uranium Mining[1]

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**In this issue:**



## Introduction

In the United States, nuclear energy accounts for 20 percent of the base load electricity generated*. We are by far the world's largest producer and consumer of nuclear energy. Yet the United States produces very little uranium, having to import over 95% of the uranium we use to fuel our nuclear power plants. Our increased demand for energy has both renewed interest in exploring and developing the rich uranium reserves we have in the U.S., as well as stimulated citizen interest and concern. On the following pages I have attempted to assemble and answer some of the most common questions I have heard from citizens about uranium mining in my work as a health physicist. - *Steve Brown*

* Base load means that the electricity is available 24 hrs every day, 365 days per year since it does not depend on environmental conditions. Only nuclear, fossil fuel and hydroelectric power plants can provide this.

## About the Author

Steve Brown has 35 years experience as a health physicist, is certified by the American Board of Health Physics and is a Diplomat of the American Academy of Health Physics. He has been President of the Central Rocky Mountain Chapter of the Health Physics Society twice. He possesses a Bachelors degree in Physics and a Masters in Physical Science. He was a high school science teacher prior to entering industry and has taught graduate courses in radiological science as an adjunct professor.

**NOTE:** the author can provide references for the basis and sources of any of the values and quantities presented in this article. Feel free to contact Steve via email: sbrown@senesusa.com

[1] This is an update of the document entitled "A Citizens Guide to Uranium" by the same author published by SENES Consultants Limited in February 2009

For more information on what is a health physicist
and on the National Health Physics Society,
visit the Society's web site @ http://www.hps.org.

## 1. What is uranium and where does it come from?

Uranium is a naturally occurring, slightly radioactive element, which has been around since the formation of the Earth 4.5 billion years ago. Chemical conditions in some locations resulted in higher concentration of uranium into what are known as ore bodies. It is a common element in Earth's crust, found in soil and rock, as well as in groundwater and seawater. One square mile of earth, one foot deep, typically contains about 2 tons of radioactive uranium. It is everywhere in varying concentrations.

## 2. How is uranium extracted from the earth?

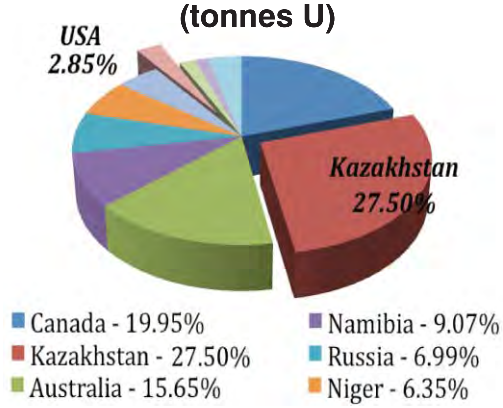
There are two basic approaches to extracting uranium from the earth. The first method is through conventional mining and milling and the second is called in-situ recovery (ISR). Conventional mining and milling methods involve extraction of large volumes of rock and soil containing uranium ore from underground or open pit mines at or near the surface. The rock is then 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" (uranium oxide) product.

Guess Why It's Called Yellowcake?

In situ recovery methods are different in that they involve reversing the natural processes that originally brought the uranium out of the groundwater millions of years ago, forming uranium roll-front ore bodies. ISR methods use oxygenated groundwater to allow the uranium to become soluble again, forming a uranium solution that is pumped to a plant on the surface. The solution is loaded onto closed resin columns or tanks where the uranium can be chemically extracted and concentrated. From this point it is processed similarly to conventional uranium mills to produce the final yellowcake product.

Uranium is mined in Colorado, Wyoming, New Mexico, Utah, Texas and other western states but the bulk of uranium used in nuclear reactors in the US is imported from other countries like Canada, Australia, Kazakhstan and several others in Africa and Central Asia. The world wide supply of uranium is shown in the figure below. Note that currently, the US must import over 95% of the uranium fuel we need from these other countries.

**World's Top Ten Uranium Ore Producers (tonnes U)**



## 3. What is uranium used for and why is it important?

The number one use of uranium is for electricity generation. Approximately 20 percent of U.S. electricity is generated by uranium fuel in nuclear power plants. There are approximately 100 nuclear power plants in the US and over 400 worldwide. In a nuclear reactor, the heat produced from uranium is used to boil water to make steam to run turbines like most other electricity generating power plants. Another use of uranium because it is an extremely dense, but relatively flexible heavy metal, is in military armor and armament as well as counterweights on ships and aircraft. In the past, uranium was also used for many years as a coloring agent in ceramics and glass.

## 4. How radioactive is uranium and uranium ore compared to other consumer products we use everyday that contain radioactive substances?

Typical uranium ore** contains about 800 picocuries or "pCi" per gram of uranium (a pCi is a measure of radioactivity – very small – about 2 atoms decaying in a minute). A "handful" of uranium ore, let's say 10 grams (about 1/3 ounce), would contain about 8000 pCi of uranium (about 50,000 pCi including uranium's other naturally occurring radioactive products). Compare this amount to a common household smoke detector which contains americium (a radioactive substance made in nuclear reactors), that contains an average of 50,000,000 picocuries; or a typical luminous wristwatch dial that contains an average of 1,300,000,000 picocuries of a radioactive form of hydrogen (called tritium – also made in nuclear reactors).

** The radioactivity of uranium ore is dependent on the amount of uranium in the rock, also known as the quality or "ore grade". The values used here are for an average of ores currently being mined in the US and assumes a grade of 0.1% (1000 parts per million of uranium in the rock). Ores from other countries (e.g., most Canadian ores) can be of much higher grade.

## 5. How much uranium is in the food we eat and water we drink everyday and in the soil and rocks under our feet?

Typical annual uranium intake in example foods (approximately):

- Whole-grain products: 10 pCi
- Bakery products: about 40 pCi
- Fresh fruit: 30-50 pCi
- Meat: 50-70 pCi
- Potatoes: about 70 pCi

Bananas are particularly high in natural radioactivity because they contain a lot of potassium. The naturally occurring radioactive form of potassium is called potassium 40 or K40 and one typical banana (6-8 ounces) contains about 800 pCi. So a "bunch" of 10 bananas contain as much radioactivity from potassium as from uranium in a handful of uranium ore. In fact, there is so much natural radioactive potassium in our own bodies that over 200,000 atoms of K40 are decaying every minute (that's almost 100,000 of those pCi!)

**Uranium in groundwater:**
The average concentration of uranium in groundwater in the US is about 2 picocuries per liter. The US Environmental Protection Agency's drinking water standard for uranium is about 20 picocuries per liter, expressed on a mass basis as 30 micrograms (millionths of gram) per liter.

However, concentrations can vary considerably from place to place depending on local geology and other factors. Numerous studies have been conducted in the US indicating levels in groundwater that are used for domestic purposes including drinking water can be many times higher than EPA's standard. In areas where uranium has concentrated into ore bodies, levels in ground water would be expected to be higher than average. For example, a recent National Laboratory study in the Nambe region of New Mexico found that over 50% of the wells tested exceeded the EPA limit with some values as high as 800 pCi/liter.

**Uranium in soil:**
Previously I had indicated that uranium is a fairly common element in the earth's crust and a square mile of earth, one foot deep, would typically contain about 2 tons of uranium. That same square mile of earth, one foot deep will also typically contain over 12 tons of naturally occurring radioactive thorium and about another 2 tons of the radioactive form of potassium (K40) we talked about earlier. That's over 16 tons of naturally occurring radioactivity in the first foot of almost any square mile of our fields, forests and back yards!

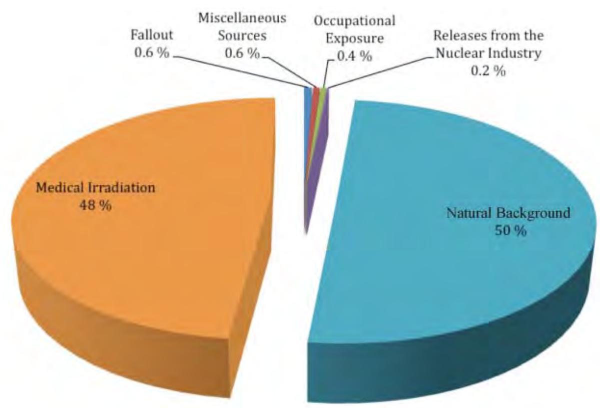
## 6. Are the existing regulations (Federal and some States) for uranium recovery facilities (mines, mills and in situ leach plants) adequate to protect the public from additional radiation exposure above our natural background exposure?

Our lifestyles, where we choose to live, what we eat and drink, has a much larger impact on our exposure to radiation than releases from uranium mines and mills or nuclear power plants. The basic exposure limits for the public that operating uranium fuel cycle facilities must comply with are 100 millirem (a unit of effective radiation dose) per year from all sources, including radon, and 25 millirem per year excluding radon (US Nuclear Regulatory Commission, US Environmental Protection Agency, Colorado Department of Public Health and Environment and the Texas Commission on Environmental Quality, e.g.).

Compare these numbers to the annual radiation doses we receive as citizens of planet earth. The U.S. average is about 300 millirem per year; the average in Colorado is about 400 with over 500 in Leadville, Colorado. Locations on the east or west coasts are typically lower than the US average, about 150 - 200 millirem per yr. This means that for someone who lives in Denver, where their daily exposure is about 1 millirem, they could "avoid" the 25 millirem by just spending a month or two with mom and dad in Virginia or hanging out on a beach on the coasts where the daily exposure is about ½ millirem per day.

The figure below depicts the typical components of human exposure to ionizing radiation in the US.

**Sources of Human Exposure to Ionizing Radiation**




It may surprise you to know that natural background radiation is generally the largest source of radiation exposure to humans (medical exposures are almost the other 50% – see chart above) and may vary considerably from place to place and over relatively small areas within a region. This is due to effects of elevation (more cosmic rays from space at higher elevations), greater levels of naturally occurring radioactive elements in soil and water in mineralized areas, and other factors.

The mining and milling of uranium and generation of nuclear energy is subject to stringent regulation at the state, national and even local levels. The US Nuclear Regulatory Commission requires the uranium plant operator to undergo a lengthy, public licensing process before receiving authorization to mill. Once approved, the mill is subject to inspections and monitoring through final reclamation and closure under strict environmental performance standards. The US Nuclear Regulatory Commission (or State agencies that the Federal government has authorized, like Colorado Texas and Utah) oversees the transportation and handling of uranium and any by-product material. These agencies must enforce health and environmental standards as required by Federal law (US Atomic Energy Act, National Environmental Policy Act, etc.). For additional information about the licensing and regulatory process for uranium processing facilities, go to http://www.nrc.gov/materials/uranium-recovery.html

## 7. What are the potential health effects from exposure to uranium?

Regarding radiation in general, the health effects are well understood. An official position of the National Health Physics Society is that below 5,000-10,000 millirem (which includes the range of both occupational and environmental exposures), the risks of health effects are either too small to be observed or non-existent. International and national authorities that establish exposure standards for workers and the public rely on the work of scientific committees of the highest professional standing for the scientific information on health effects of radiation. These scientific committees include the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the National Academy of Science's Biological Effects of Ionizing Radiation (BEIR) Committee, the National Council on Radiation Protection & Measurements (NCRP) and others.

However, it is important to note, that since uranium is a heavy metal like lead and mercury, the most important potential health impacts are due to its chemical properties, not because of its radiological properties or radiation.

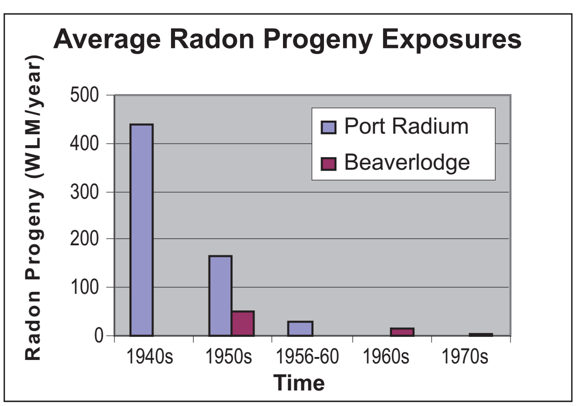
Possible health effects in populations living close to uranium mines and mills also have been well studied. No additional effects have been observed when compared to the health status of similar populations not living nearby a uranium mine or mill.

## 8. But what about the known health impacts to many uranium miners who worked underground in the 1950s and 1960s compared to working conditions today?

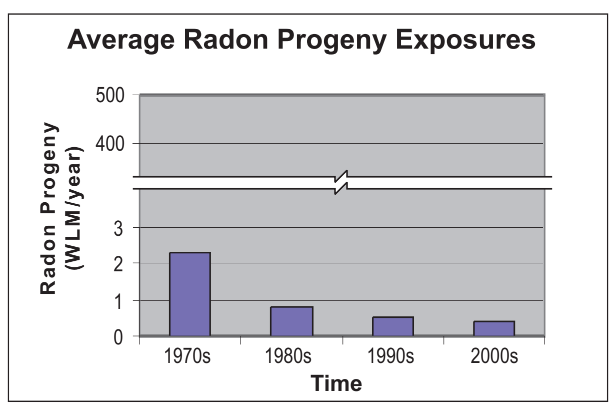
Mine workers years ago worked in conditions that by today's standards would be considered unacceptable. They worked in poorly ventilated underground mines with levels of exposure hundreds or even thousands of times greater than what current Federal standards allow. Today, Federal agencies like the Occupational Safety and Health Administration, Mine Safety and Health Administration, and the U. S. Nuclear Regulatory Commission implement and enforce laws to better protect workers throughout American industry.

Exposure to radon has been the major health risk to uranium miners. As indicated above, in the early days of uranium mining, the exposures of miners to radon (actually, the short-lived decay products of radon called "radon progeny" measured in units called "working level months" – WLM) were much higher than exposures to modern uranium miners. The figures below show how the exposures of miners in Saskatchewan Canada have decreased over time from high to very low levels. The earlier miners exposure decreased from more than 400 WLM per year in the 1940's to about 2 WLM per year by early 1970. Exposures are even lower today, an average of about ½ of a WLM per year, about 800 times less than the early mining days. In fact, an epidemiological study of modern miners in Saskatchewan concluded that the occupational exposure to radon is small compared to the likely natural variation in exposure to residential radon. As a point of

**Exposure of Saskatchewan Uranium Miners to Radon 1940 to 1970**




**Exposure of Modern Saskatchewan Uranium Miners to Radon 1970 to Present**



comparison, it is not uncommon in the US for natural radon exposure levels in our homes to be near or in excess of EPA's recommended 4 pCi per liter standard. This level of exposure is about the same as ½ of a WLM per year or about the same as the average exposure of uranium miners in North America.

## 9. Don't scientists disagree on many of the health and safety concerns associated with uranium and radiation exposure in general?

In fact, the vast majority really do not. Much of 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 and/or by their governments around the world. As citizens, we need to evaluate for ourselves what I'll refer to as the relative "weight of evidence". This includes evaluating the expertise of the source of the information. Many people have degrees in various areas of expertise, but having an advanced degree in something doesn't necessarily make one an expert in something else. (If I had a dangerously high fever, I probably wouldn't consult my dentist, despite the fact that she is also a doctor.) We should consider just as important one's life and work experience relevant to the subject matter as we evaluate the credibility of individuals and weight of their evidence. Most of the citizens I interact with are not scientists, and the "weighing" of contradicting claims on what are often complex and emotional issues can be difficult and challenging. When faced with these apparent "disputes" and upon objective examination, we will often find that the relative weights of these claims are not at all equal. As citizens, we need to evaluate the "weight of evidence" for ourselves and draw our own conclusions.

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## Corporate Profile


***SENES Consultants Limited*** is a Canadian wholly employee-owned company that specializes in the fields of energy, nuclear, and environmental sciences . Since its inception in 1980, the company has participated in over 5,500 projects throughout Canada, United States, South America, the Caribbean, Africa, Australia, Europe, Asia, the Middle East and the Far East. The business philosophy of the firm is to provide an exceptional level of service to our clients while ensuring that our common interest in preserving the environment is enhanced. In the rapidly changing world in which we live, creative and innovative solutions are often required to resolve complex problems. We at ***SENES*** pride ourselves on staying in the forefront of technological advancement to allow us to continue to satisfy our clients' needs. We strongly believe that this attribute distinguishes us from our competitors.

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