# WE LIVE IN A RADIOACTIVE ENVIRONMENT – THE NATURAL RADIATION BACKGROUND AND ITS VARIABILITY IN THE UNITED STATES

RADIATIONPROS

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The magnitude and variability of natural background radiation can be used as a benchmark to providesome perspective on the radiation doses received from Naturally Occurring radioactive Material (NORM) associated with water treatment facilities. This is particularly relevant sincea large percentage of our background radiation exposure is a direct result of naturally occurring uranium, radium, radon and associated other decay products in the soil and rocks under our feet, in the air we breath and in the food and water we consume every day.

Natural background radiation exposure to humans is ubiquitous, unavoidable and highly variable depending on where you live. In the present context, "radiation" is assumed to meanionizing radiation, which has enough energy to alter living cells as opposed to microwaves, radioand TV waves, ultraviolet radiation and other forms of non-ionizing radiation. People are exposed to cosmic radiation from the sun and outer space that is constantly bombarding the earth's atmosphere. Humans are constantly immersed in a field of cosmic radiation that varies with elevation (higher doses from cosmic radiation are found at higher elevations). Naturally occurring radioactive materials are present in the rocks and soil of the earth, in the houses we live in and in the buildings where we work, as well as the food and drink we consume.

There are radioactive aerosols and gases in the air we breathe and even our own bodies contain naturally occurring radioactive elements. The level of this inescapable natural "background" radiation exposure varies greatly from place to place. For example, according to the U.S. National Council on Radiation Protection and Measurements (NCRP 1987), background soil in the U.S. contains a mean of 3.1 parts per million (ppm) of uranium (and 6.5 ppm of thorium) although much higher concentrations, especiallyin areas of mineralization, are not uncommon (NCRP 2009, UNSCEAR 2000). A square mile of the earth's surface one foot deep, just about anywhere in the temperate zones, contains over a ton of radioactive uranium.

Natural background radiation, which comes from a number of sources, typically results in a dose rate of roughly about 200 to 400 millirem [(1)] per year (UNSCEAR 2000), although some places inthe world, including parts of the U.S., experience much higher exposure rates. The average annual exposure from natural background radiation in the U.S. (311 millirem/y) is shown in Table 1 and Figure 1 (NCRP 2009). The typical variability across the US, demonstrating how where one chooses to live can affect their background radiation exposure by several hundred millirems a year, is depicted in Table 2.

**Table 1: Exposure to Natural Background Radiation in the United States**

| Source of Exposure | Average in U.S. (millirem[1]/year) |
|---|---|
| Internal, inhalation (radon and thoron) | 228 |
| External, cosmic (space) | 33 |
| Internal, ingestion (food and water) | 29 |
| External, terrestrial (rocks and soil) | 21 |
| Total | 311 |

Table 1 shows the major components of natural background radiation, including terrestrial radiation (uranium, radium, thorium and potassium 40 in soil, rocks and water), cosmic radiation (high energy gamma rays from space) and internal radiation (from food, water and radon gas from natural uranium and radium decaying

[1] A millirem (mrem) is a unit of effective radiation dose. It is related to the amount of energy absorbed by human and other factors. 1,000,000 microrem = 1,000 millirem = 1 rem g in the ground).

**Figure 1: Natural Background Radiation in the United States**

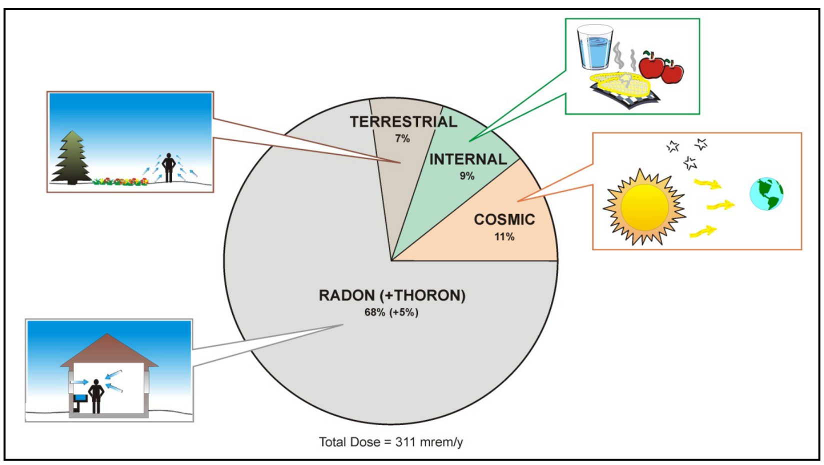



**Table 2: Comparison of Average Radiation Backgrounds In US vs. Colorado (Units of millirem / year)**

| Source | Colorado [a] | Florida [a] | Illinois [a] | Leadville CO [b] |
|---|---|---|---|---|
| | | | | |

| | | | | |
|---|---|---|---|---|
| Cosmic Radiation | 49 | 27 | 28 | 85 |
| Terrestrial Radiation | 39 | 13 | 24 | 97 |
| Internal Radiation including Radon Inhalation, Food and Water Ingestion | 300 | 54 | 181 | 344 |
| Totals | 387 | 93 | 233 | 526 |

[a] From USEPA 2005 [b] From Moeller 2006

As shown in Table 2, natural radiation exposure can vary considerable from place to place across theUnited States or over relatively small areas within a region. This is due to effects of elevation (higher cosmic radiation exposure at higher elevations), greater levels of naturally occurring radioactive elements in soil and water in mineralized areas (e.g. igneous formations in Rocky Mountains) and other factors like local geology and geochemistry.

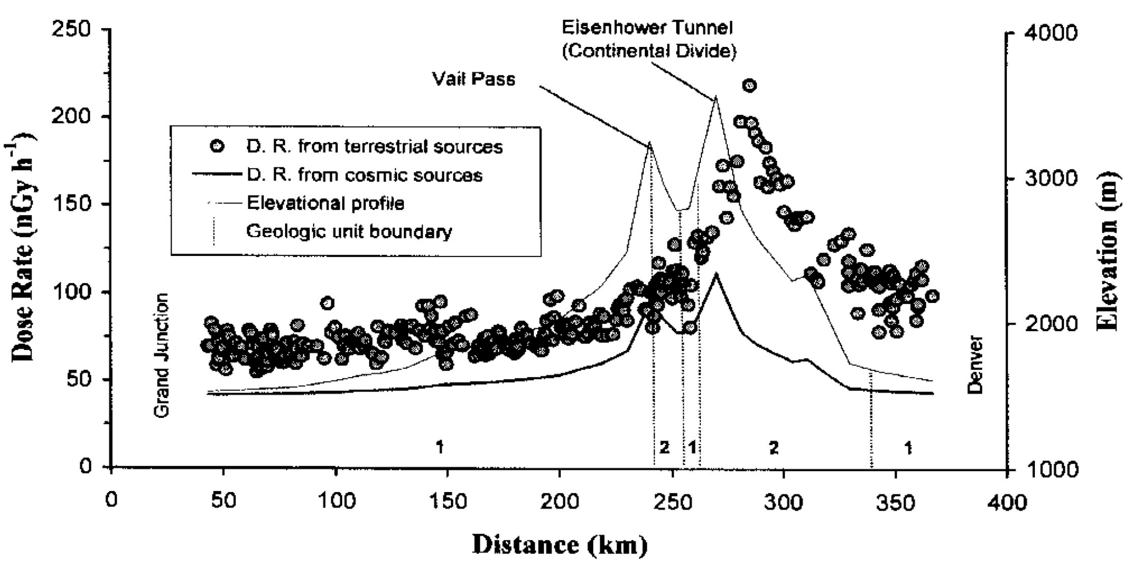
According to the NCRP, exposure to radon (or specifically, Rn-222), primarily while indoors, isresponsible for almost 70% of the average dose from background radiation, although radon doses arehighly variable. In the U.S., the average indoor radon concentration at home is 1.25 picocuries per liter (pCi/L), and the average outdoor concentration is 0.40 pCi/L (NCRP 2009). A picocurie (pCi) is a measure of the amount of radioactivity and is a unit used only in the US. It is the amount of radioactivity where approximately two atoms decay per minute. This is a very small amount of radioactivity. A handful of soil from your backyard will have 5-10 or more pCi in it from naturally occurring radioactivity, including uranium, thorium and radium.

However, indoor concentrations can often be much higher. The Colorado Department of Public Health and Environment's Radon web site indicates that about half of the homes in Colorado haveradon levels higher than the U.S. Environmental Protection Agency recommended action level of 4pCi/L. ( https://cdphe.colorado.gov/understanding-radon )

An additional perspective is depicted in Figure 2, which shows the change in radiation exposure rate due to a variation in elevation and mineralization as one travels across the Interstate 70 corridor through the Rocky Mountains between Denver and Grand Junction, Colorado.

**Figure 2: Variability of Terrestrial and Cosmic Radiation Background Across The Interstate 70 Corridor Of Colorado** (units of nanograys per hour) (2).

Note that moving a hundred miles can change exposure by a factor of 4. (Stone, 1999)




(2) A nanogrey is an international unit of absorbed dose. 100 nanogrey is approximately equivalent to 0.01 millirem

**Naturally Occurring Radioactivity in Food**

Radioactive isotopes are inherent in all foods. Natural radioactive isotopes, such as potassium 40 (K-40), carbon-14 (C-14), tritium (H-3), natural uranium, thorium and radium and various other radioactive elements are part of the food chain. Plants assimilate radionuclides into their structure through respiration, transpiration, and soil uptake.

Typical annual uranium intake by humans in some example foods include (NCRP,1984; Welford, 1967):

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

In some instances, these radioisotopes may be concentrated into certain parts of the plant where other stable isotopes of the same element are also being concentrated, such as the roots, fruits, or nuts. This effect is especially notable in fruits with high levels of potassium, such as bananas.

One banana contains approximately 422 mg of potassium (Chiquita Banana, 2013). The radioactive isotope of potassium mentioned above, K-40, has a natural occurrence of 0.0117% (Strom et al, 2009). Therefore, of the 422 mg of potassium in a banana, about 0.5 mg are radioactive. This translates into about 360 pCi of radioactivity per banana from K-40. If you were to eat a bunch of 10 bananas, you have consumed about 3600 pCi of radioactive K-40.

To put this in perspective, the human body contains 1 to 2 grams of potassium per kilogram of body mass. A 70 kg person therefore, would contain 70 to 140 grams of potassium. This means a person that weighs 70 kg might contain between 8 and 16 mg of radioactive K-40, or between 60,000 to 120,000 pCi of radioactivity from K-40 alone. Annually, this results in a dose to that person of 13.6 millirem / year (Strom et al, 2009). However, note that eating extra bananas will not necessarily increase your average annual radiation dose from extra K-40 since your body eliminates excess potassium through homeostasis.

**Naturally Occurring Radioactivity in Groundwater**

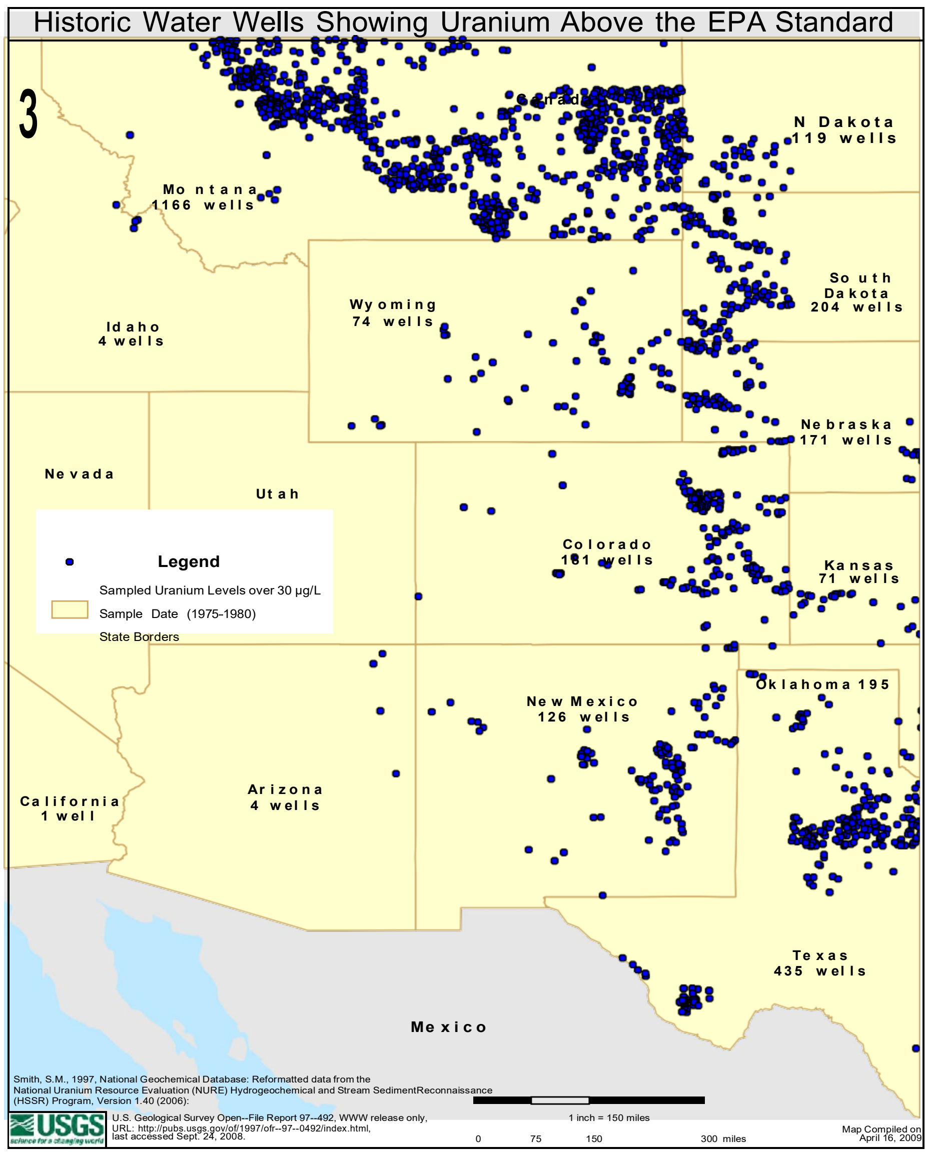
Using uranium as an example, the average concentration of natural uranium in groundwater in the USis about 2 pCi per liter (NCRP 1984). The US Environmental Protection Agency's drinking water standard for uranium is about 20 picocuries per liter (expressed on a mass basis as 30 micrograms per liter (USEPA, 2001). However, concentrations can vary considerably from place to place depending on local geology and other environmental factors. A number of studies of uranium content of US domestic water sources indicate levels in groundwater that are used for domestic purposes, including drinking water, can be many times higher than EPA's standard (Hakonson 2002, CEPA 1997, USGS 2006). Figure 3, reproduced from USGS 2006, depicts results of uranium concentrationsin well water for a large number of domestic wells in the Western U.S. that were sampled under the direction of the United States Geological Survey (USGS) as part of the National Uranium Resource Evaluation Program of the 1970s. Each marked location identifies domestic water well(s) in which the reported uranium concentrations exceeded the 30 micrograms per liter drinking water criteria (USEPA2001).

The EPA also has several other drinking water criteria for radionuclides, which are:

- ≤ 15 pCi / liter gross alpha (many of the natural uranium and thorium series decay productsemit alpha particles)
- ≤ 4 millirem per year from beta particles and gamma ray emitters
- ≤ 5 pCi / liter combined Ra 226 and Ra 228

Note that similarly to the circumstances of naturally occurring uranium discussed above as demonstrated in Figure 3, it is not uncommon that radium concentrations in domestic groundwater wells also exceed the EPA drinking water criteria (UW 2020, MDE 2000, USGS 1988)

**FIGURE 3: Uranium Concentrations In Domestic Water Wells – US NURE Program(From USGS 2006)**



The basic regulatory public exposure limits applicable to facilities or activities that use radioactive material are 100 millirem per year above the natural background dose from all sources includingradon and 25 millirem / year excluding radon. Examples of Federal and Colorado radiation exposure limits for occupational workers and the public are presented in Table 3.

**Table 3: Example Federal and Colorado Radiation Dose Limits**

| Exposure Condition | Limit | Regulatory Reference |
|---|---|---|
| Trained Radiation Worker Annual Exposure [(3)] | 5000 millirem /year | USNRC: 10 CFR 20.1201, *Occupational Dose Limits; Colorado: 6 CCR 1007-1 Part 4.4.1, Occupational Dose Limits* |
| Radiation Exposure Limit for Members of the Public - General | 100 millirem / year including radon | USNRC: 10 CFR 20.1101, *Radiation Dose Limits for Individual Members of the Public;* Colorado Department of Public Health and Environment: 6 CCR 1007-1 Part 4.parapraph 4.14.1, *Radiation Dose Limits for Individual Members of the Public* |
| NRC license termination and unrestricted release of site ("w/o radon") | 25 millirem / year | U.S. Nuclear Regulatory Commission. Consolidated Decommissioning Guidance - Decommissioning Process for Materials Licensees, NUREG 1757, Vols. 1–3; 2006. |
| EPA – Public exposure limit for releases from Nuclear Fuel Cycle | 25 millirem / year | 40 CFR 190 - Environmental Radiation Protection Standards for Nuclear Power Operations |
| EPA Drinking Water Standards | 4 millirem / year from beta and gamma emitters | 40 CFR 191.66 - Maximum contaminant levels for radionuclides |

(3) Note that water treatment plant operators who work under a radioactive material license issued by the State of Colorado are typically trained as radiation workers.

Compare the public exposure limits in Table 3 to the annual radiation doses we receive as citizens ofplanet Earth as depicted in Table 1 and 2 above. Note that, for example, although the basic Federal (and Colorado) annual exposure limit for a member of the public is 100 mrem above background,people who choose to live in Colorado vs. lets say as an example, Florida, will received on theaverage 200 - 300 millirem more radiation exposure every year. For those people who choose to livein Leadville, the difference compared to their relatives in Florida is an average of 300 - 400 milliremhigher radiation exposure every year of their lives that they choose to live in Leadville.

**Conclusions**

We Live in a Radioactive Environment. Naturally occurring radioactive materials are present in the rocks and soil of the earth, in the houses we live in and in the buildings where we work, as well as thefood and drink we consume. There are radioactive aerosols and gases in the air we breathe and even our own bodies contain naturally occurring radioactive elements. The level of this inescapable natural "background" radiation exposure can vary greatly from place to place.

- Our bodies contain radioactive materials
- Our lifestyles, where we choose to live, what we eat and drink, has a much larger impact onour radiation exposure than control at the regulatory limits for public exposure
- Our biosphere is powered by nuclear fusion reactions in the sun
- Our earth and weather are respectively shaped by the heat from radioactive decay in theearth's core and radiation from space

# It's Always Been This Way

**For further information contact Radiation Pros at** info@radpros.com **or at 720-771-0200**

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