

BASICS: Radiation's Impact on the Human Body

Prepared by Cindy Folkers, Beyond Nuclear

Naturally occurring, artificially available.

Radionuclides contaminating the water and the environment in your community are those that occur naturally, but they have been dug up, concentrated and otherwise subjected to industrial processes which have made them much more available to be inhaled or ingested. How quickly a radionuclide is absorbed into, or released from, the body depends on the chemical it has formed while in the environment. Once a radionuclide is taken into the body, where the nuclide settles tells you which organs it will damage. If someone continues to breathe contaminated air or eat contaminated food, radionuclides may not ever wash out of their body, ensuring a continual exposure.

How radiation damages

In order to better understand radiation damage, we need to know about components of the human body. The human body is made up of blood, and organs that in turn are made up of tissues. These tissues can be different in different organs, but they are all made up of cells and cells contain many components that make our bodies function properly. One of these is the DNA (deoxyribonucleic acid), which is our genetic material. Damaging DNA is one of the ways radiation causes diseases like cancers or heart problems. The quality of DNA damage is different depending on the type of radiation. Some radiation can cause more complex or more widespread damage, but all radiation types can cause damage, which can start the process of causing disease.

Natural radionuclides like the ones contaminating your environment primarily give off alpha particle radiation, but they also give off some beta and gamma. If you are exposed to alpha particles, "substantial doses of radiation (0.5–1.3 Gy) are delivered to individual cells that are traversed by a single alpha particle no matter how low the dose to the whole body."¹

"Irrespective of their source, alpha particles produce the same patterns of secondary ionizations and localized damage to biological molecules ([IARC 2001](#)), thus the important difference between different alpha emitters would be in what tissues they preferentially accumulate in, and thus what tissues are preferentially irradiated."²

But in order for a nuclide to collect in a certain organ, it has to travel there through other parts of the body, which means it can be causing damage to organs along the way as it travels, not just the organ where it deposits.

Focus on pregnancy and early childhood exposures

Early human life stages (pregnancy and childhood) are uniquely vulnerable to damage from radiation, as are fetuses. Emphasizing impact on reproductive health is important for three reasons: 1) the vulnerability of pregnancy and childhood can not only lead to health impacts during these stages, but exposures during these stages can cause diseases years later when the person is an adult; 2) this lifetime risk from early developmental exposure is all but ignored in radiation exposure standards in the U.S.; 3) Most reasonable people think protection of child health is not controversial, making it a pressure point for action.

A hormone called estrogen is important both in pregnancy and in children as they develop into adults. There is evidence within the scientific research that radioactivity can impact the same biological pathways as estrogen. It could be that this impact on estrogen accounts for apparent vulnerabilities of women and children to radiation:

“Estrogen, as a potent molecule involved in number of biological pathways during development and adulthood, shows close interaction with pathological processes launched by overexposure to ionizing radiation which should be included in future research and radiation protection.”³

ISOTOPES OF CONCERN

The following nuclides are among those of concern to the community. Some of these have already been found in your community in drinking water, in soil, and in the bodies of people.

URANIUM

EPA allowable level: 30 micrograms per liter in drinking water

Contamination has been found in soil, water and drinking water, including that of a local school.

Where does it collect in the body? Uranium mimics the mineral calcium and can enter your body if you breathe it in, eat or drink food or water that contains

it. Calcium is essential for growth and maintenance of healthy bones and functioning of muscle. Replacing healthy, non-radioactive calcium with radioactive uranium can cause a host of subtle and not so subtle health impacts. There is also evidence that the element uranium mimics the essential hormone estrogen, so incorporating uranium into your body would not only impact the estrogen pathway because of its radioactivity, but also because of the chemistry of uranium itself. Uranium in oxide form is abundant and readily dissolved into the body. If you inhale uranium into the lung, it can take years for it to leave the lung and be absorbed into the rest of your body. While it is in the lung, it is damaging lung cells. When it leaves the lung, about 85% of it goes to bone with some of the remainder traveling to the kidneys, and a smaller remainder going to the liver.⁴

As much as 20% of uranium can be absorbed through the gut if ingested. For neonatal gastrointestinal tract (GI) absorption can be faster. Fasting and iron deficiency will increase these absorption rates by up to 3&1/2 times. The time uranium remains in the bone is usually between 180 and 833 days. "...following absorption into the body, uranium forms soluble complexes with bicarbonates, citrates, and proteins, all of which are present in high concentrations in the body."⁵

Health impacts

Absorption of uranium into the human body can cause kidney damage, in form of tissue lesions. Bone diseases including osteoporosis occur if uranium is injected. If taken orally, research on mice has shown uranium is a developmental toxicant.⁶ Research indicates that uranium levels below the EPA water standard limit cause negative reproductive health impacts. In mice, uranium was associated with decreased fertility, embryo/fetal toxicity including teratogenicity, and reduced growth of the offspring. Reduction in testosterone, and significant decreases in the mean litter size and in the viability of offspring was also associated with uranium ingestion. Fetal body weight was significantly decreased in mice at 1 and 2mg/kg/d exposure to uranium. Researchers also reported the number of total internal and total skeletal defects increased, and growth rate in offspring of exposed females was significantly lower than in control animals.⁷

In addition, transplacental exposure to uranium caused fewer primordial follicles in developing pup ovaries, resulting in fewer ovulated ova. The long-term consequence of fewer primordial follicles can be accelerated ovarian failure. Increases in birth defects were significantly related to the mother's proximity to

uranium tailings. "In another study, the incidence of reproductive or gonadal cancer in New Mexico Native American children and teenagers is 8-fold greater than that in age matched non-Native American individuals."⁸ "DU caused significant external anomalies, and caused a significant decrease ($p < 0.05$) in the weight and diameter of placentas, the number of the embryos, their body weight and crown-rump length of fetuses."⁹

Lifetime risks due to low birth weight include diabetes, heart disease, high blood pressure (all of which together constitute something called "metabolic syndrome"), obesity.

THORIUM

EPA allowable level in drinking water

15 picocuries per liter for gross alpha (not including radon and uranium), 4 mrem for beta and photon radiation. Thorium contamination is not tested for except at the facility where it might have come from. It is not measured for in the surrounding environment.

Where does it collect in the body?

In general, thorium collects in the same places in the body whether inhaled or ingested. Thorium mimics the mineral iron, which is necessary for healthy bones and blood. Target organs include the lungs, lymph nodes, bones,¹⁰ liver and spleen.¹¹

Health impacts

At higher medical and occupational doses, thorium is associated with lung cancer, pancreatic cancer, colorectal cancers, chronic respiratory diseases, liver damage, and other serious illnesses. "Skeletal sarcomas, thorostrastomas, and sarcomas of the reticuloendo-thelial system have been reported from a study of patients receiving intravenous injections of thorostrast, a colloidal solution of thorium oxide that was used as a contrast medium for diagnostic radiographic studies from the 1930s to the 1950s."¹²

The residents of households in the vicinity of a New Jersey thorium waste disposal site and in the vicinity of a contaminated brook have increases in birth defects and liver disease; residents had not been tested for radioactive materials uptake in their bodies. "Surveys of the New Jersey Department of Environmental Protection showed readings of 40-1491 uR/hour...in areas of their surrounding environment that were classified as contaminated."¹³

Studies of placental uptake of thorium show that the weight of human placenta containing nuclides is higher than that of placenta free from radioactive nuclides, "...i.e. even small concentrations of radioactive nuclides in placenta, possessing "excess" energy create conditions for accelerated cell division, and as a result, increased weight of placenta."¹⁴ Since the placenta is responsible for delivering nutrients to fetus, more nutrients could mean a bigger baby. However, a larger birth weight, like a low birth weight, is not healthy and is associated with higher lifetime risk of obesity, diabetes, and heart disease.¹⁵ Further, the accelerated cell division (more rapid cell growth) associated with increased nuclides in the placenta could promote a cancerous condition.

RADIUM

EPA allowable level

Combined radium 226/228 of 5 picocuries per liter in drinking water. It is not routinely tested for in unregulated water sources.

Where does it collect in the body?

Like uranium, radium mimics the necessary mineral calcium and crosses the placenta in the same ratio as in the mother's blood.

Health impacts

Because of its similarity to calcium, ingested radium lodges in bone, causing rapid changes in bone structure, red blood cell formation (hematopoiesis) and causing bone sarcomas.¹⁶ Inhalation into lungs thru burning of fossil fuels gradually enters bloodstream.¹⁷ Chronic exposure to radium in humans, by inhalation, has resulted in acute leukopenia (decrease of white blood cells). Oral exposure has resulted in anemia, necrosis of the jaw, abscess of the brain, and terminal bronchopneumonia. No information is available on the developmental or reproductive effects of radium in humans or animals. EPA has not classified radium, radon or uranium for carcinogenicity.¹⁸

RADON

EPA allowable level

4 picocuries per liter in air. The World Health Organization (WHO) says radon action level should be 2.7 picocuries per liter. Radon is not routinely measured in either the environment or inside homes in the community.

Where does it collect in the body

Radon is a radioactive gas that itself doesn't accumulate in organs, but its decay products can. When it is inhaled, the dose from radon is given mainly to the lung. There can be some cross over to the blood through the lung tissue.¹⁹ Radon can travel to the brain where it leaves its decay products to irradiate brain tissue. It can pass through the placenta where it irradiates the developing embryo or fetus.

Health impacts

Radon and cigarette smoke act synergistically, meaning that the sum of the damage they do when they are together is greater than what each of them does apart from the other. This happens because the progeny of radon, which would not normally be breathed in, can attach to particles and dust in the cigarette smoke.²⁰ Radon is thought to be the second major cause of lung cancer after smoking,²¹ responsible for 15K to 22K cancer deaths per year in the US alone.²²

Studies performed in the U.S. have demonstrated a 50% increased lung cancer risk with prolonged radon exposure above the EPA's action level of 4 pCi/L. When radon travels to the brain, its decay products can cause Alzheimer's and Parkinson's. Some research indicates that radon causes multiple sclerosis.²³ Chronic exposure to radon in humans and animals via inhalation has resulted in respiratory effects including chronic lung disease, pneumonia, fibrosis of the lung, decreased lung function.²⁴

"...radon can pass through the placenta and into the developing child. If the developing child is only in the embryo phase, and a radon particle forms a progeny and deposits anywhere, emitting alpha radiation, the formation of DNA lesions will most likely kill it. At such an early point in human development, the presence of inheritable DNA adducts or lesions causes too much genomic instability to allow for a viable organism. On the other hand, if the developing child is in the fetal stages, most of the bodily development has already occurred. In this case, a radon particle passing into the fetus would likely move to lipid portions of the unborn child, namely the brain and other organs. Since brain development is most crucial in this phase, ionizing radiation at this point might not kill the organisms but may cause severe inhibition in brain development leading to mental retardation after birth."²⁵

POLONIUM

EPA Allowable level

15 picocuries gross alpha per liter in drinking water. Not measured for, except at uranium facilities, and therefore not found in environments outside of these facilities.

Where does it collect in the body?

Natural polonium has become more available for biological uptake because of a number of different industrial processes²⁶ and from the phosphate fertilizer used in tobacco farming.²⁷ Po-210 has similarity to sulfur and has affinity for certain amino acids and proteins, properties that can indicate how it will behave in your body.²⁸ Polonium's movement within our bodies has been studied extensively but despite this, we still don't know how to interpret the data correctly for a number of reasons, and much of the important biological and toxicological research on ²¹⁰Po is more than four decades old.²⁹

Po-210 can be inhaled and ingested, collecting in the liver, kidneys, bone marrow and gonads. Polonium accumulates in the radiosensitive ovaries to such a great degree, that the ovary may be the critical organ in determining the lowest damaging dose of this nuclide. Polonium also accumulates in the yolk sac of the embryo and in the fetal and placental tissues.³⁰

Health impacts

Polonium is toxic because of its radioactivity rather than its chemical properties. Low-level exposure to polonium may have subtle, long-term biological effects because of its affinity for reproductive and embryonic and fetal tissues where exposure to a single alpha particle may kill or damage critical cells. Polonium can damage the placenta. Little is specifically known about the effects of polonium exposure to the embryo and fetus, however, fetal exposure could cause failure of implantation or miscarriage or major malfunctions. It can cause an increased incidence of chromosomal breaks and translocations resulting in childhood cancer. At particular stages of development, a single cell can be responsible for creating future cells and tissues, and irradiation may cause mutagenic effects in these cells that is later manifested as different diseases. An unrecognized outcome for women exposed to environmental polonium may be subfertility.³¹

RADIOACTIVE LEAD

EPA allowable level

15parts per billion (ppb) in tap water for non-radioactive lead. Stable lead is measured for, but not found in public water supplies.

Where does it collect in the body?

Lead absorbs more when inhaled than ingested. Either path will result in just about the same endpoint deposition. Radioactive lead damages both from its radioactive and chemical nature.³² The majority of lead collects in bones and teeth. The rest collects in all organs of the body. Lead collects in the placenta and crosses into the developing embryo or fetus.

Health impacts

A high exposure to lead can lead to poisoning. Symptoms include abdominal pain, constipation, fatigue, headaches, irritability, loss of appetite, memory loss, pain or tingling in the hands or feet, weakness.

Symptoms of chronic, lower level lead exposure include miscarriage, stillbirths male and female infertility, behavioral problems, nervous system damage, reduced intelligence, neurological effects, mental retardation, high blood pressure, heart disease, kidney disease, cancer. For radioactive lead, the risk of cancer increases over non-radioactive lead, but the chemical disease risks remain.

The biological half-life of lead (the time it takes for the poison to loose half of its impact on your body so it becomes half as effective as it originally was at poisoning you) in adult human blood has been estimated to be from 28 days to 36 days. ^{33,34}

DIETARY REMOVAL AND REPAIR

Scientific research has shown that certain foods help remove contamination from your body and help it repair the damage caused: cilantro³⁵, chlorella³⁶, pectin³⁷, milk thistle³⁸, garlic³⁹, brassicas⁴⁰, black tea⁴¹, fermented foods (research has focused on miso⁴² and kefir⁴³)

Only foods that have been scientifically researched are included in the above list, therefore other beneficial foods may exist that have not been studied.

In addition to diet, sweating removes heavy metals.⁴⁴

Of course any food should not be contaminated if it is used to counter the effects of heavy metal and radiation exposure. Loading your diet with these foods will help cleanse and repair your system, but continuing exposure by inhaling or ingesting contamination should be avoided even with use of these foods.

¹ Seiler, et al. [Occurrence of 210Po and Biological Effects of Low-Level Exposure: The Need for Research](#) *Environ Health Perspect.* 2012.

² Seiler, 2012.

³ Fucic, et al. Interaction between ionizing radiation and estrogen: What we are missing? *Medical Hypotheses*, Volume 77, Issue 6, 966 - 969

⁴ Craft et al. *DEPLETED AND NATURAL URANIUM: CHEMISTRY AND TOXICOLOGICAL EFFECTS.* *Journal of Toxicology and Environmental Health, Part B*, 7:297–317, 2004.

⁵ Craft 2004.

⁶ Craft 2004.

⁷ Raymond-Whish, et al. *Drinking Water with Uranium below the U.S. EPA Water Standard Causes Estrogen Receptor-Dependent Responses in Female Mice.* *Environmental Health Perspectives.* VOLUME 115. NUMBER 12. December 2007.

⁸ Whish 2007.

⁹ Mirderikvand et al. Embryo Toxic Effects of Depleted Uranium on the Morphology of the Mouse Fetus. *Iranian Journal of Pharmaceutical Research : IJPR.* 2014;13(1):199-206.

¹⁰ Ulsh, et al. [Retrospective Dose Reconstruction for Thorium, 232 Activities at the Mound Laboratory](#), Preliminary Report, NIOSH, 2012.

¹¹ [Thorium-232 and Uranium-238: The Toxicology of Radioactive Substances.](#) edited by A. A. Letavet, 1970

¹² Najem, et al. [Health Effects of a Thorium Waste Disposal Site.](#) *AJPH.* April 1990.

¹³ Najem. 1990.

¹⁴ Rakhmanbek, et al. [The effect of low concentrations of radioactive nuclides on morphometric characteristics of human placenta.](#) *EHP abstracts.* 2013.

¹⁵ Seppa. [Big babies: High birthweight may signal later health risks.](#) *Science News.* May 16, 2014.

¹⁶ Canu et al. [Health Effects of Naturally Radioactive Water Ingestion: The Need for Enhanced Studies.](#) *Environ Health Perspect* 119:1676-1680 (2011)

¹⁷ [TOXICOLOGICAL PROFILE FOR RADIUM.](#) Agency for Toxic Substances and Disease Registry U.S. Public Health Service in collaboration with:U.S. Environmental Protection Agency. 1990.

¹⁸ [Radionuclides \(including Radon, Radium and Uranium\) Hazard Summary.](#) EPA. 2000, 2016?

¹⁹ Field, R. William (1999). ["Radon Occurrence and Health Risk" \(PDF\).](#)

²⁰ Biermann, A.H.; Sawyer, S.R. (1995-05-01). ["Attachment of radon progeny to cigarette-smoke aerosols".](#) *Information Bridge.*

²¹ Catelinois O, Rogel A, Laurier D, et al. (2006). ["Lung cancer attributable to indoor radon exposure in france: effect of the risk models and uncertainty analysis".](#) *Environ. Health Perspect.* **114** (9): 1361–6.

²² ["Radon and Cancer: Questions and Answers".](#) *National Cancer Institute.*

²³ Groves-Kirkby et al. [Environmental Radon Gas and Degenerative Conditions – An Overview.](#) IRPA, Paris. 2006.

²⁴ [Radionuclides \(including Radon, Radium and Uranium\) Hazard Summary.](#) EPA. 2000, 2016?

²⁵ [Radon: Molecular Action and Genetic Effects.](#) *University of Minnesota School of Public Health.*

²⁶ Leggett et al. [A systemic biokinetic model for polonium.](#) *The Science of the Total Environment* 275. 2001. 109-125.

²⁷ Muggli et al. [Waking a Sleeping Giant: The Tobacco Industry's Response to the Polonium-210 Issue.](#) *Am J Public Health.* 2008 September. 98(9). Pp 1643–1650.

²⁸ Leggett et al. [A systemic biokinetic model for polonium.](#) *The Science of the Total Environment* 275. 2001. 109-125.

²⁹ Leggett et al. 2001.

³⁰ Seiler 2012.

³¹ Seiler 2012.

³² [Health Problems Caused by Lead.](#) CDC. 2013.

³³ [TOXICOLOGICAL PROFILE FOR LEAD](#) U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES Public Health Service Agency for Toxic Substances and Disease Registry. 2007.

³⁴ CDC 2013.

-
- ³⁵ Sears. [Chelation: Harnessing and Enhancing Heavy Metal Detoxification—A Review](#) The Scientific World Journal. Volume 2013.
- ³⁶ Sears 2013
- ³⁷ Sears 2013
- ³⁸ [Greenlee et al. Clinical applications of Silybum marianum in oncology.](#) Integr Cancer Ther. 2007 Jun;6(2):158-65.
- ³⁹ Sears 2013
- ⁴⁰ Sears 2013
- ⁴¹ Ghosh, et al. [Antagonistic effects of black tea against gamma radiation-induced oxidative damage to normal lymphocytes in comparison with cancerous K562 cells.](#) Radiat Environ Biophys. 2014 Nov;53(4):695-704.
- ⁴² Watanabe. [Review Beneficial Biological Effects of Miso with Reference to Radiation Injury, Cancer and Hypertension.](#) J Toxicol Pathol 2013; 26: 91–103.
- ⁴³ Matsuu. [The protective effect of fermented milk kefir on radiation-induced apoptosis in colonic crypt cells of rats.](#) J Radiat Res. 2003 Jun;44(2):111-5.
- ⁴⁴ Sears 2013