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Canada and the US Department of Energy Promoting Small Nuclear Reactors

With neither Canada nor the US having a solution for disposal of spent nuclear fuel, both countries are pursuing nuclear energy which makes more radioactive waste.

Canada is pushing small modular reactors, typically less than 300 mega-watts-electric (MWe). Top contenders for support in Canada appear to be X-Energy's XE-100 [75 Megawatts-electric (MWe); GE Hitachi's BWRX-300 [300 MWe], and the Terrestrial Energy Integral Molten Salt Reactor (ISMR) [200 MWe]. [1]

In the US, the Department of Energy is pursuing any and every kind of reactor, from the fast neutron sodium-cooled reactor Natrium to X-energy's TRISO fueled high-temperature gas cooled reactors. There is a mania in the wide diversity which ensures maximum spending on the nuclear research proposals.

The NuScale Small Modular Reactor project slated for the Idaho National Laboratory site continues researching its third proposed site at the INL after the first two sites were deemed unworkable. A single NuScale facility would include up to a dozen 50 or 60 megawatt-electric (MWe) light-water reactors in one pool. For NuScale reactors, the natural circulation only works if the reactors remain vertical in the pool of water where each reactor will frequently be lifted by overhead crane, for refueling.

The Department of Energy has also committed $80 million to help fund the construction of a 345-megawatt-electric (MWe) "Natrium" demonstration fast neutron liquid-sodium-cooled power reactor proposed by GE-Hitachi and Terrapower and it hopes Congress will provide additional funding. The Department of Energy has allocated millions of dollars for Advanced Reactor Concepts and General Atomics to design small sodium-cooled reactors.

Sodium-cooled reactors are fast neutron reactors rather than thermal (or slow) neutrons in water moderated nuclear reactors. The Department of Energy's Office of Nuclear Energy has justified the need for the Versatile Test Reactor, also a fast neutron reactor, by the fast-neutron reactors whose construction it is supporting.

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[1] Paul Day, *Reuters Events*, "Canada lays foundation for expansive SMR industry," April 27, 2021. https://www.reutersevents.com/nuclear/canada-lays-foundations-expansive-smr-industry?utm_campaign=NEI%2028APR21%20NEI%20%28smr%29&utm_medium=email&utm_source=Eloqua

In this way, it is "bootstraping" the Versatile Test Reactor by creating a need for it that would not otherwise exist, according to Frank von Hippel. [2]

GE Hitachi Nuclear Energy is working with the Idaho National Laboratory on the VTR conceptual design based on its PRISM reactor, which was based on the Experimental Breeder II reactor. [3] The EBR II which was operated by Argonne National Laboratory – West at the Idaho site which is now the Materials and Fuels Complex at the INL, although the EBR II has been dismantled.

World-wide, experience with fast reactors has been fraught with high expense and maintenance problems. The success story, France's sodium-cooled Super Phenix only managed to operate about 6 percent of the time. Japan's fast reactor, Monju, was a dangerous money pit, operating only 250 days in two decades. [4]

The Department of Energy's Federal Register notice that is in Appendix A of the VTR EIS – actually quotes DOE as having an objective of the VTR to lead to **reduced nonproliferation concerns**. Translated this means DOE's goal is to *increase the proliferation concerns* – which may be an error by the DOE, but it is exactly the opposite of what we all want – which is to reduce proliferation concerns and keep nuclear weapons material like plutonium-239 out of nuclear weapons.

According to the Department of Energy, there's a definite need for a fast test reactor. [5] But actually, no one in the U.S. electric utility industry is wanting fast reactors.

The *Idaho Falls Post Register* quoted the Savannah River Site Watch press release criticizing the estimated $3 to $6 billion dollar project for the VTR and the inevitable cost increases. [6]

A copy of the Draft VTR EIS can be downloaded at https://www.energy.gov/nepa or https://www.energy.gov/ne/nuclear-reactor-technologies/versatile-test-reactor.

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[2] Frank N. von Hippel, Bulletin of the Atomic Scientists, "Plutonium programs in East Asia and Idaho will challenge the Biden administration," April 12, 2021. https://thebulletin.org/2021/04/plutonium-programs-in-east-asia-and-idaho-will-challenge-the-biden-administration/

[3] Press Release, GE Hitachi, "GE Hitachi and PRISM Selected for U.S. Department of Energy's Versatile Test Reactor Program," November 13, 2018. https://www.ge.com/news/press-releases/ge-hitachi-and-prism-selected-us-department-energys-versatile-test-reactor-program

[4] *World Nuclear Industry Status Report*, "Japanese Government Pulls the Plug on Fast Breeder Reactor Monju," December 23, 2016. https://www.worldnuclearreport.org/Japanese-Government-Pulls-the-Plug-on-Fast-Breeder-Reactor-Monju.html

[5] U.S. Department of Energy, Office of Nuclear Energy, "DOE: There's a Definite Need for a Fast Test Reactor," March 1, 2019. https://www.energy.gov/ne/articles/doe-theres-definite-need-fast-test-reactor

[6] Nathan Brown, *The Idaho Falls Post Register*, "DOE publishes reactor impact statement," December 22, 2020.

Department of Energy promoting large clusters of MARVEL reactors

The Department of Energy, while basing the safety case on a single MARVEL reactor, intends that multiple reactors would be used in practice. The MARVEL liquid metal microreactors would be used in clusters, although each individual reactor is far less than one megawatt-electric. [7]

The MARVEL design is based on a 1960s design for space missions. [8]

The sodium-cooled reactor would be fueled by high-assay low-enriched uranium (HALEU) from available research materials at the INL. It will use Stirling engines to transfer energy from the core to make electricity.

According to the Department of Energy, MARVEL is a sodium-potassium cooled, thermal microreactor with a power level of less than 100 kilowatts of electricity. The EA states the thermal power level is expected to provide only 20 kilowatts of electricity, which would light something like 300 light bulbs. This *is* tiny, yet the Department of Energy considers anything up to 20 megawatts-thermal (or 20,000 kilowatts-thermal) to be included in the category of "microreactor."

The Draft Environmental Assessment was issued for public comment last January [9] Tami Thatcher's public comment submittal on MARVEL is at http://www.environmental-defense-institute.org/publications/CommentDOEMARVELdea.pdf

The fuel for a single MARVEL reactor will be 150 kilograms of about 20 percent uranium-235 enrichment in 36 fuel pins and the fuel material will be uranium-zirconium-hydride in a stainless steel cladding. Each fuel pin is about 38-in. long and will be sodium-bonded.

In contrast, existing large commercial nuclear reactors use roughly 100,000 kilograms of fuel, but at less than 5 percent uranium-235 enrichment. A large commercial nuclear reactor typically generates an average of about 3,000 megawatts of thermal energy and about 1000 MW of electricity. [10]

A single MARVEL reactor is actually a micro-sized reactor, but a large number of them are likely to be clustered at a facility using them.

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[7] Department of Energy, Office of Nuclear Energy, "New MARVEL Project Aims to Supercharge Microreactor Deployment," April 13, 2021. https://www.energy.gov/ne/articles/new-marvel-project-aims-supercharge-microreactor-deployment

[8] Gabrielle N., Tech Times, "US Department of Energy Backs MARVEL Tech Development, Could be Operational in Three Years," April 22, 2021. https://www.techtimes.com/articles/259410/20210422/us-department-of-energy-backs-microreactor-tech-development-renewable-energy-source-us-doe-marvel-project.htm

[9] *Draft Environmental Assessment for the Microreactor Applications Research, Validation and Evaluation Project at Idaho National Laboratory (DOE/EA-2146),* January 2021 at https://www.id.energy.gov/ or https://www.id.energy.gov/insideNEID/PDF/Final%20MARVEL%20Draft%20EA%20DOE%20EA-2146.pdf

[10] One thousand (1000) watts is equal to 1 kW and 1,000,000 watts is equal to 1 megawatt (MW).

DOE plans to test the MARVEL reactor design inside the Transient Reactor Test facility (TREAT) at the Idaho National Laboratory (INL).

Disposal of the waste generated by the MARVEL design testing has not be clearly stated by the Department of Energy, but loop holes for disposal of fuels used in experiments could mean that the spent nuclear fuel is buried at the Idaho National Laboratory.

And despite the deception in the MARVEL environmental assessment, the Department of Energy has no spent fuel disposal program.

US Department of Defense Project Pele for Microreactor Development

The US Department of Defense (DOD) has selected two competing microreactor companies in an initiative called Project Pele, one led by BWXT Advanced Technologies, LLC, Lynchburg, Virginia; and the other by X-energy, LLC, Greenbelt, Maryland. [11]

The microreactor designs are to provide from one to five Megawatts of electrical power for at least three years of operation at full power.

The microreactors would be mobile. They would be transported for use and then presumably removed at a later date. The US military's track record on environmental polluting its bases, shipyards and places where artillery is tested or used is such, that the difficulty would be to find any place that the military did not leave behind harmful environmental pollutants. Another problem is that having one of these mobile reactors, used or unused, on the free-way next to you in a snowstorm pile up car accident or having one operating where you work or where you live.

Project Pele involves the United States Army, the Department of Energy, the Nuclear Regulatory Commission, the National Aeronautics and Space Administration, and the National Nuclear Security Administration.

The Department of Energy, meanwhile, has subsidized Oklo, a $25-million startup company, to construct a 1.5 MWe "microreactor" to use HALEU fuel on the Idaho National Laboratory's site to demonstrate what is an extravagantly costly power source for remote regions, according to Frank von Hippel. [12]

Canada is also interested in microreactors (in addition to small nuclear reactor). The Ultra Safe Nuclear Corporation (USNC) is working on a 5 MW gas-cooled reactor demonstration

[11] Department of Defense, "Strategic Capabilities Office Selects Two Mobile Microreactor Concepts to proceed to Final Design," March 22, 2021. https://www.defense.gov/Newsroom/Releases/Release/Article/2545869/strategic-capabilities-office-selects-two-mobile-microreactor-concepts-to-proce/

[12] Frank N. von Hippel, Bulletin of the Atomic Scientists, "Plutonium programs in East Asia and Idaho will challenge the Biden administration," April 12, 2021. https://thebulletin.org/2021/04/plutonium-programs-in-east-asia-and-idaho-will-challenge-the-biden-administration/

project at Ontario's Chalk River site. Another reactor that would be transportable is being considered with the Westinghouse Canada eVinci Micro Reactor. [13]

The mobile nuclear reactors mean that no one can escape living near an impending nuclear disaster, contaminating their homes, cars, property, businesses, as well as their families and their own bodies.

A rough summary of some of the currently proposed reactors in Table 1.

Table 1. Summary of nuclear reactors currently receiving U.S. research dollars.

Reactor Category ***Reactor name***	**Reactor type/ Fuel type**	**MW-thermal**	**MW-electric**	**Fissile Material**	**Special notes**
Materials Testing *Versatile Test Reactor*	Fast neutron, sodium-cooled, U-Pu-Zr	300 MW-th	0	Uranium-plutonium-zirconium metal	Existing materials testing at the Advanced Test Reactor is 250 MW-thermal, thermal neutron, light-water cooled
Commercial electrical power TerraPower & GE Hitachi *Natrium*	Fast neutron, sodium-cooled, U-Zr	?	345 MWe	Uranium-zirconium-hydride using HALEU	
Commercial electrical power X-energy's *Xe-100*	High-temperature gas cooled, TRISO	?	Xe-100, 80 MWe; 4-pack is 320 MWe	TRISO (tristructural isotropic) uranium fuel particles from HALEU	TRISO fuel used in Fort St. Vrain reactor (but FSV used U-233 fissile material)
Commercial electrical power (Small Modular Reactor) *NuScale*	Light-water pressurized reactor, standard PWR fuel with MOX and other fuels envisioned	?	NuScale 50 MWe (hopes to amend license to 60 MW); 12-pack 720 MWe	<4.95 percent enriched standard PWR fuel, hope to use plutonium mixed oxide fuel (MOX) and/or higher enrichment fuels	

[13] Paul Day, *Reuters Events*, "Canada lays foundation for expansive SMR industry," April 27, 2021. https://www.reutersevents.com/nuclear/canada-lays-foundations-expansive-smr-industry?utm_campaign=NEI%2028APR21%20NEI%20%28smr%29&utm_medium=email&utm_source=Eloqua

Reactor Category *Reactor name*	Reactor type/ Fuel type	MW-thermal	MW-electric	Fissile Material	Special notes
Mobile reactors	Variety	?	< 20 MWe	variety	Wide range of sizes and accident consequences
	Project Pele, BWXT Advanced Technologies, LLC,		1 to 5 MWe		Department of Defense
	Project Pele, X-energy, LLC, high temperature gas cooled		1 to 5 MWe		Department of Defense
	Oklo, a $25-million startup company		1.5 MWe	HALEU	Department of Energy
	Ultra Safe Nuclear Corporation (USNC), gas-cooled reactor demonstration project		5 MWe		Canada at Ontario's Chalk River site
	Westinghouse Canada eVinci Micro Reactor		1 MWe to 5 MWe		
Micro *MARVEL*	Sodium-potassium-cooled, HALEU	100 kW-th	"less than 100 kWe" Expect 20 kWe (0.02 MWe)	150 kg of 20 percent enriched U-235 (U-Zr-Hydride fuel in stainless-steel cladding	Testing planned at INL's TREAT facility

Table notes: MW-th is megawatts-thermal energy, MWe or simply MW is megawatts-electric energy. HALEU is high assay low-enriched uranium, produced by the Idaho National Laboratory in a highly environmentally airborne polluting pyroprocessing operation. Note regarding past, current or under construction reactors: the nominally 1000 MWe Westinghouse AP1000 under construction is a light-water pressurized reactor, 1000 MWe, fuel of uranium oxide of 4.55 percent uranium-235 enrichment; existing Advanced Test Reactor, 250 MW-thermal, 93 percent enriched uranium-235; formerly operated Fort St. Vrain high-temperature gas-cooled reactor, 330 MWe, used TRISO fuel; formerly operated Peach Bottom reactor, 40 MWe; formerly operated Hanford's Fast Flux Test Facility reactor was a 400 MW-thermal fast neutron sodium-cooled reactor; formerly operated INL's Experimental Breeder Reactor II (EBR-II) was a fast neutron sodium-cooled pool-type reactor of 62.5 MW-thermal (19 MWe), see Perry

et al., Seventeen Years of LMFBR Experience: Experimental Breeder Reactor II (EBR-II), CONF-820465—2, April 1982 at https://www.osti.gov/servlets/purl/6534205 .

Chernobyl Radioactive Contamination Continues Spreading and Harming People

According to a 2021 *Greenpeace* article, around five million people in Ukraine, Belarus and Russia still live in the radioactive contamination from the 1986 Chernobyl nuclear disaster. [14] These people constantly receive new doses of radiation. [15] [16]

Forest fires are common in the radiologically contaminated forests near Chernobyl. These fires not only endanger fire fighters because the radionuclides located in the upper soil layers may be released into the air to spread far and wide to many people.

The "exclusion zone" around the Chernobyl nuclear power plant remains contaminated with radionuclides. In a 2020 *Greenpeace* article, they noted cesium-137, strontium-90, americium-241, plutonium-238 and plutonium-239. [17]

In a 2015 report by Evangeliou and others, they studied the cesium-137, strontium-90, plutonium-238, plutonium-239, plutonium-240 and americium-241. [18] The report acknowledges that these radionuclides remain in significant amounts even though the Chernobyl accident was over 30 years ago. Other radionuclides from Chernobyl, including the uranium and the plutonium radioactive decay progeny have been ignored. Chernobyl's low enriched fuel means uranium-238 was prevalent. Radium-226 is a decay product of uranium-238 and also of curium-242 and of plutonium-238. Curium-242 decays to plutonium-238.

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[14] Andrey Allakhverdov, *Greenpeace*, "Do we need a new Chernobyl?" April 23, 2021. https://www.greenpeace.org/international/story/47384/nuclear-do-we-need-a-new-chernobyl/

[15] The estimates for the number of cancer fatalities caused by the Chernobyl accident range from the Idaho National Laboratory's claim during its public meetings to dispel fears about the Chernobyl accident where they said that Chernobyl only caused the increase of a few thousand thyroid cancers and that thyroid cancer usually does not cause death. UNSCEAR, the U.S. Nuclear Regulatory Commission, the U.S. Department of Energy, and others made estimates of the cancer fatalities of less than 30,000 deaths (see Table 7.9 of the report in the next footnote). In contrast, the estimate by Yablokov and others in *Chernobyl: Consequences of the Catastrophe for People and the Environment* was that world-wide Chernobyl probably will cause an additional one million cancer deaths by 2004 (see page 210 of report in the next footnote). In addition to cancer and leukemia deaths, are the birth defects and increased rates of death from increased illnesses for exposed populations.

[16] Alexey V. Yablokov, Vassily B. Nesterenko, and Alexey V. Nesterenko, Annal of the New York Academy of Sciences, "Chernobyl: Consequences of the Catastrophe for People and the Environment," Volume 1181, 2009. http://www.strahlentelex.de/Yablokov_Chernobyl_book.pdf

[17] Rashid Alimov, *Greenpeace*, "Chernobyl still burns," April 23, 2020. https://www.greenpeace.org/international/story/30198/chernobyl-still-burns-forest-fires-ukraine-nuclear-radiation/

[18] Evangeliou, N. *et al., Nature*, "Resuspension and atmospheric transport of radionuclides due to wildfires near the Chernobyl Nuclear Power Plant in 2015: An impact assessment." *Sci. Rep.* **6**, 26062; doi: 10.1038/srep26062 (2016). https://www.nature.com/articles/srep26062

Radium-228 and radium-224 are decay products of natural thorium and also of curium-244, plutonium-240 and other reactor-made radionuclides. The report states that monitoring has been conducted, but the monitoring remains unexplained and no monitoring data are provided.

This report by Evangeliou and others is rather misleading and understates the potential radiation doses in that it highlights that their estimated effective dose in the exclusion area would be about 100 mrem/yr. Their report gives the impression that no harmful doses are occurring in or outside the exclusion zone. But this report later admits that they excluded ingestion of radiologically contaminated food and water. The uncertainty in the range of radiation doses is not addressed. The uneven distribution of radionuclides, the incomplete set of radionuclides considered and the bioaccumulation of radionuclides in certain foods has been ignored.

Of the radionuclides considered in the 2015 report, all but the cesium-137 are bone-seeking radionuclides and all, including the cesium-137 give a dose to bone marrow. The report does not mention how once the plutonium and americium gets into the body, it remains in your bones for the rest of your life.

As decay progeny are produced by radioactive decay, radionuclides like plutonium, americium, curium and neptunium as well as uranium and thorium become more radioactive over time, over hundreds of thousands of years and beyond 1 million years. See the decay series of uranium-238, thorium-232, uranium-235 and uranium-233 (or americium-241) in the Environmental Defense Institute April 2020 newsletter at http://www.environmental-defense-institute.org/publications/News.20.April.pdf .

For the radionuclides addressed in the report by Evangeliou and others, and some additional radionuclides that are likely also present, some basic information is summarized in Tables 2 and 3.

Bone marrow is where the stem cells for blood cells are from, including the white blood cells that make up most of the immune system. The compromise to the immune system, however, is ignored by the radiation protection models and in the conversion of absorbed dose to effective dose in Sieverts or rems.

The radiation community has focused on complete death of the bone marrow leading to death within weeks of an acute exposure as an effect that could be observed and has focused on lower chronic doses that may result in cancer or leukemia. [19] [20] [21] The criteria for death to the bone

[19] Emergency Preparedness and Response Section, International Atomic Energy Agency, Jointly sponsored by IAEA and WHO, *Development of an extended framework for emergency response criteria*, IAEA-TECDOC-1432, January 2005. https://www-pub.iaea.org/MTCD/publications/PDF/TE_1432_web.pdf

[20] International Atomic Energy Agency, General Safety Guide, No. GSG-2, *Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency*, 2011. https://www-pub.iaea.org/MTCD/publications/PDF/Pub1467_web.pdf

[21] J. S. Evans et al., Prepared for U.S. Nuclear Regulatory Commission, *Health Effects Models for Nuclear Power Plant Accident Consequence Analysis*, NUREG/CR-4214, Rev. 2, Part I, Completed September 1993. https://www.nrc.gov/docs/ML0500/ML050030192.pdf This revision incorporated, in part, Addendum II for alpha

marrow from alpha emitters was based on very limited study of animals. The endpoint of damage to the immune system has never been considered by the official radiation community.

Table 2. Survey of selected radionuclide inhalation and ingestion lifetime cancer mortality risk.

Radionuclide	Lifetime Cancer Mortality Risk per pCi Inhalation	Lifetime Cancer Mortality Risk per pCi Ingestion	Notes
Cesium-137	8.1E-12	2.5E-11	Strong gamma emission used in aerial surveys. Mimics potassium in the body. Studies of the Chernobyl accident indicate that it is associated with increased risk of blood disorders, cardiac arrhythmias, autoimmune diseases, neuromuscular diseases, reproductive problems and cancer.
Stronium-90	1.0E-10	7.5E-11	Mimics calcium in the body and is a tooth and bone seeker.
Iodine-129	6.2E-12	3.3E-11	Long-lived and mobile fission product found to dominate long-term harm when inhaled or ingested. Collects in thyroid
Technetium-99	1.3E-11	2.3E-12	Long-lived and mobile fission product found to dominate long-term harm when inhaled or ingested. Tc-99 collects in thyroid
Americium-241	2.4E-8	9.5E-11	Bone seeker, see plutonium-239. Don't be misled by the 432 year half-life because it has many longer lived decay progeny.
Curium-242	1.4E-8	3.2E-11	See plutonium-239
Curium-242	2.3E-8	7.5E-11	See plutonium-239
Neptunium-237	1.5E-8	5.8E-11	See plutonium-239
Plutonium-238	3.0E-8	1.3E-10	See plutonium-239
Plutonium-239	2.9E-8	1.3E-10	ANL fact sheet says laboratory studies with experimental animals exposed to high levels of plutonium can cause decreased life spans, diseases

emitters. See also the March 1993 Addendum II, for alpha emitters and including monitoring near Chernobyl which can be found at https://www.osti.gov/servlets/purl/10153043

Radionuclide	Lifetime Cancer Mortality Risk per pCi Inhalation	Lifetime Cancer Mortality Risk per pCi Ingestion	Notes
			of the respiratory tract, and cancer. Once in the blood stream, plutonium is highly retained in the body, especially in bone and the liver. Plutonium is associated with cardiovascular disease, leukemia, lung cancer, breast cancer, childhood cancers, infant mortality and transgenerational mutations. Uranium, plutonium, americium decay progeny ultimately result in an isotope of lead.
Uranium-234	1.1E-8	6.1E-11	See uranium-238. Uranium-234 is a decay product of uranium-238 and has a much higher specific activity, in curie per gram, than either U-235 or U-238.
Uranium-235	9.5E-9	6.2E-11	See uranium-238
Uranium-236	9.9E-9	5.8E-11	See uranium-238
Uranium-238	8.8E-9	7.5-E-11	Bone, kidney. ANL Fact Sheet states: "reproductive effects in laboratory animals and developmental effects in young animals…" Uranium is associated with cancer, miscarriage, still births, childhood cancers, birth defects, infertility, brain disorders, kidney disease and trans-generational mutations. Spent nuclear fuel is usually over 90 percent unfissioned uranium. Uranium is released in reactor accidents and nuclear weapons testing, yet is rarely mentioned or monitored.
Radium-226	2.4E-8	2.9E-9	Radium-226 is a decay product of uranium-238 or plutonium-238 or uranium-234 or thorium-230. Mimics calcium in the body and is

Radionuclide	Lifetime Cancer Mortality Risk per pCi Inhalation	Lifetime Cancer Mortality Risk per pCi Ingestion	Notes
			stored in bone and teeth

Table source of information: Argonne National Laboratory, EVS, Human Health Fact Sheet, August 2005 at https://www.remm.nlm.gov/ANL-ContaminationFactSheets-All-070418.pdf Source used by ANL was Federal Guidance Report 13, U.S. Environmental Protection Agency, 402-R-99-001, September 1999.

Picocurie is 1.0E-12 curies. Lifetime cancer mortality risk ignores cancers that were caused but not the cause of death, ignores non-cancer illnesses such as increased risk of heart disease, and ignores genetic effects.

Alpha emitters (from most uranium, plutonium and curium radionuclides) are more able to cause double-strand DNA breaks that are misrepaired.

Table 3. Selected radionuclide federal drinking water maximum contaminant levels.

Radionuclide	Half-Life (Primary decay mode)	Typical Decay Progeny	Drinking Water Federal Maximum Contaminant Level (MCL)
High activity fission products			
Cesium-137	30.2 year (beta)	Barium-137m (gamma)	160 pCi/L
Strontium-90	29.1 year (beta)	Yttrium-90 (beta)	8 pCi/L
Actinides (include thorium, protactinium, uranium, neptunium, plutonium, americium, curium, californium and others)			
Thorium-230	77,000 year (alpha)	Radium-226 Many others	15 pCi/L
Protactinium-231	33,000 year (alpha)	Radium-223 Many others	15 pCi/L
Uranium-238	4,470 million yr (alpha)	Uranium-234, Thorium-230, Radium-226 Many others	10 pCi/L Total U 30 microgram/L
Uranium-234	240,000 year (alpha)	Thorium-230 Many others	Total U 30 microgram/L
Uranium-235 (Fissile material)	700 million yr (alpha)	Pa-231 Ra-223 Many others	Total U 30 microgram/L
Uranium-233 (Fissile material)	160,000 year (alpha)	Radium-225 Many others	Total U 30 microgram/L
Uranium-236	23 million yr (alpha)	Thorium-232 Many other	Total U 30 microgram/L
Neptunium-237	2,144 million yr (alpha)	Uranium-233 Radium-225 Many others	15 pCi/L
Plutonium-238	88 year (alpha)	Uranium-234 Thorium-230 Radium-226	15 pCi/L

Radionuclide	Half-Life (Primary decay mode)	Typical Decay Progeny	Drinking Water Federal Maximum Contaminant Level (MCL)
		Many others	
Plutonium-239 (Fissile material)	24,000 year (alpha)	Uranium-235 Many others	15 pCi/L
Plutonium-240	6,500 year (alpha)	Uranium-236 Many others	15 pCi/L
Plutonium-241	14.4 year (beta)	Americium-241 Neptunium-237 Uranium-233 Many others	300 pCi/L
Plutonium-242	380,000 year (alpha)	Uranium-238 Many others	15 pCi/L
Curium-242	0.45 year (alpha)	Plutonium-238 Uranium-234 Many others	15 pCi/L
Curium-244	18 year (alpha)	Plutonium-240 Uranium-236 Many others	15 pCi/L
Americium-241	430 year (alpha)	Neptunium-237 Uranium-233 Many others	15 pCi/L
Radium-226	1600 year (alpha)	Radon-222 Many others	5 pCi/L for radium-226 and radium-228 combined
Radium-228	5.75 year (beta)	Thorium-228 Radium-224 Many others	5 pCi/L for radium-226 and radium-228 combined

Table notes: Table only highlights the dominant decay mode, selected decay progeny, and selected parent progeny and is not exhaustive. Picocurie/liter (pCi/L)

U.S. Nuclear Regulatory Commission Technical Evaluation Report for the U.S. Department of Energy Idaho National Laboratory Site Draft Section 3116 Waste Determination for Idaho Nuclear Technology and Engineering Center Tank Farm Facility, October 2006. https://www.nrc.gov/docs/ML0624/ML062490142.pdf

Idaho National Laboratory, "Evaluation of Groundwater Impacts to Support the Natural Environmental Policy Act Environmental Assessment for the INL Remote-Handled Low-Level Waste Disposal Project," INL/EXT-10-19168, Rev. 3, August 2011. Tables 4 and 9.

Regarding waste classification errors for plutonium-241, curium-242 and curium-244, see IEER.ORG publication, *Science for Democratic Action*, "The Curious Case of Curium-242, Curium-244 and Plutonium-241," Volume 6, Number 1, May 1997.

The official radiation community, such as the World Health Organization and the International Commission on Radiation Protection (ICRP) has actively ignored that human health studies conducted by independent scientists.

The radiation community has long known that white blood cell counts for lymphocytes as well as platelets correspond to the radiation dose received. But the blood is expected to return to normal over time. But the situation is far different for the inhalation (and ingestion) of plutonium and americium which are retained in the body.

The problem is that for Chernobyl "liquidators" (or radiation workers) receiving an estimated 25 rem, their blood counts have been noted as not returning to normal in the decades following the accident. People who were not liquidators but just live in the Chernobyl contamination and each contaminated food also have abnormal blood counts. Studies have found that people living in the Chernobyl fallout have compromised immune systems.

In the summary of studies of victims of the 1986 nuclear disaster at Chernobyl, *Chernobyl: Consequences of the Catastrophe for People and the Environment*, the wide range of health effects from exposure to radiation was explained, including cancer and leukemia but including many other illnesses. There were observations of the adverse effect of radiation on the immune system.

Along with many illnesses, the people exposed to higher levels of radiation during and following the Chernobyl nuclear accident had blood changes, intensified infectious and parasitic diseases such as viral hepatitis and respiratory viruses. [22]

In summary, the human immune system depends on the health of bone marrow. Unfortunately, various in-depth studies, many of them published in Russian, have been actively ignored by radiation health communities. [23]

Various radionuclides affect bone marrow, either by strong gamma rays (external or internal radiation) or by internal uptake into bone tissue. Irradiated bone marrow cells mean damaged blood cells that make up the immune system. Increased ionizing radiation means damage to the human immune system; yet, any death not by cancer is not counted as a health harm by ionizing radiation by the nuclear promoting agencies such as the U.S. Department of Energy or the U.S. Nuclear Regulatory Commission as they evaluate the harm of radiological releases.

The consequences of radiation exposure, including living in radioactive fallout, includes immunodeficiency.

The number of peripheral blood leukocytes in people who evacuated the Chernobyl exclusion zones remained significantly lower even 7 to 8 years after the 1986 Chernobyl accident.

Immune deficiencies in children were more prevalent in children irradiated *in utero*. Immune status of children correlated with the level of radiological contamination where they lived.

In summary, the review of the real lessons from the Chernobyl accident cannot be learned without reading the review of independent studies in *Chernobyl: Consequences of the Catastrophe for People and the Environment*. [24]

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[22] Alexey V. Yablokov, Vassily B. Nesterenko, and Alexey V. Nesterenko, Annal of the New York Academy of Sciences, "Chernobyl: Consequences of the Catastrophe for People and the Environment," Volume 1181, 2009. http://www.strahlentelex.de/Yablokov_Chernobyl_book.pdf

[23] See April 2021 Environmental Defense Institute article "With Southeast Idaho COVID-19 Hotspots, It's Time to Review the Effect of Radiation on the Immune System"

More radioactive phosphogypsum stacks planned for Pocatello

According to the Idaho Falls Post Register, a new law, HB 239, will spell out new standards for proposed new phosphogypsum stacks in Pocatello, Idaho. There is already a stack at the J.R. Simplot Don Plant. [25]

There are concerns that the new law removes Department of Environmental Quality oversight from the stacks and that groundwater monitoring will not be required.

The phosphate ore contains uranium and thorium and their radioactive decay progeny. Sulfuric acid is used to dissolve the ore and make fertilizer. The leftover waste may be called phosphogypsum. The phosphogypsum has also been called "slag" and in Idaho, has been used for some road beds and in the concrete for home foundations.

Pollution from the existing Simplot "gyp-stack" has already made its way into the Portneuf River system, stated Shannon Ansely, according to the article.

There have recently been pollutants entering Tampa Bay from failure of a Florida gyp-stack. [26]

The Shoshone-Bannock Tribes have concerns that previous environmental impact statements were poorly done and that the existing phosphogypsum stacks are polluting the Portneuf River and also that wind carries the radioactive material to the Reservation and the cities of Chubbuck and Pocatello, according to The Idaho Falls Post Register article last December. [27] In addition, waste from the FMC Corporation's operation is stored on the Fort Hall Reservation. [28]

The U.S. Environmental Protection Agency collected data from samples taken in 1980 for use in a comparison to areas near Pocatello, and selected data are presented in Table 4. [29] While this data excluded radionuclides such as cesium-137 or plutonium that likely would have been present, the data are informative because of the detailed assessment of uranium-234, uranium-235, and uranium-238 for various locations in Idaho. Even though these results were presented in terms of mrem/yr lung dose, **it is the proportions of each of these radionuclides that is of interest.** Natural uranium would have consistent proportions. This same report evaluates the radiation dose from living in a home made with a concrete foundation containing the phosphogypsum waste. The waste was also used in some road beds.

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[24] Alexey V. Yablokov, Vassily B. Nesterenko, and Alexey V. Nesterenko, Annal of the New York Academy of Sciences, "Chernobyl: Consequences of the Catastrophe for People and the Environment," Volume 1181, 2009. http://www.strahlentelex.de/Yablokov_Chernobyl_book.pdf

[25] John O'Connell, *The Idaho Falls Post Register*, "New state law sets standards for phosphate mining waste rock stacks," April 30, 2021.

[26] Herald Tribune.com, "Piney Point leak spotlights phosphogypsum stacks in Florida," April 7, 2021.

[27] Keith Ridler, *The Idaho Falls Post Register*, "Tribes sue to stop Idaho land swap amid pollution concerns," December 11, 2020.

[28] Press Release, *The Idaho Falls Post Register*, "Decision confirms tribal jurisdiction over FMC," January 13, 2021.

[29] E. G. Baker, H. D. Freeman, and J. N. Hartley, *Idaho radionuclide exposure study: Literature review*, October 1, 1987.

At Arco, the proportion of uranium-235 to uranium-238 is higher than in naturally occurring uranium and it is also higher than occurring in the Pocatello area, despite higher uranium levels overall in Pocatello due to the phosphate ore industry. The higher levels of uranium-235 at Arco would be explained by INL air emissions from the past reprocessing of highly enriched uranium (HEU) spent fuel at the INL, due to nightly wind reversals and close proximity to INTEC.

The proportion of U-234 to U-238 by activity (and by lung dose) would be 50/50 for natural uranium. But as seen in the Table 4, the amount of U-234 is often higher than U-238 which is indicative of influences of weapons fallout and/or nuclear reactor fuel. I have noted this to be the case to some extent generally throughout the northwest and not just near the INL.

Table 4. Average Annual Lung Dose (mrem/yr) for Insoluble Radionuclides, 1980.

Radionuclide	Sewage plant near Pocatello RR	Hayes Fire Station, Pocatello	Pocatello airport	Pocatello courthouse	Chubbuck school	Howe, Idaho	Arco, Idaho
U-234	2.3	0.37	0.41	0.41	0.63	0.12	0.23
U-235	0.13	0.033	0.061	0.11	0.068	0.023	0.06
U-238	1.8	0.32	0.32	0.29	0.58	0.10	0.17
Ratio of U-235/ U-238	***0.072***	***0.103***	***0.19***	***0.379***	***0.117***	***0.23***	***0.35***

Table notes: E. G. Baker, H. D. Freeman, and J. N. Hartley, *Idaho radionuclide exposure study: Literature review*, October 1, 1987.

The ratio of U-235 to U-238, by activity, shows Arco, Idaho having a ratio of 0.35 when naturally occurring uranium would have a ratio of 0.047. So, we are seeing levels of uranium-235 in our environment that are far above naturally occurring levels but, in the table above, the levels are usually below 0.23.

A curiously high proportion of uranium-235 near the Pocatello courthouse, which points to interesting things going on in Pocatello with highly enriched uranium, not tied directly to INL emissions or to weapons fallout and definitely not related to the phosphate ore industry.

Environmental monitoring for the Idaho National Laboratory does not include monitoring and reporting uranium or thorium isotopes, U-238, U-235, and U-234, or their progeny, or thorium isotopes even though the INL and former nuclear weapons testing, globally and at the Nevada Test Site, radiological releases included uranium along with plutonium and radioactive fission and activation products. See the decay series of uranium-238, thorium-232, and others in the Environmental Defense Institute April 2020 newsletter at http://www.environmental-defense-institute.org/publications/News.20.April.pdf .

The Idaho Department of Environmental Quality folks have often blamed high airborne gross alpha levels in southeast Idaho on the Pocatello phosphate fertilizer facilities as a cover for Idaho National Laboratory releases and resuspension of past releases from the soil.

Articles by Tami Thatcher for May 2021.