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Given the High Rate of Thyroid Cancer Idaho Falls, A Review of the Radionuclides that Contribute to Thyroid Cancer

Last month, I pointed out that Bonneville County, where Idaho Falls is located, has double the thyroid cancer rate compared to the rest of Idaho, based on the Cancer Data Registry of Idaho (CDRI) for the year 2017. [1]

Table 1. Bonneville County thyroid cancer incidence rate compared to the rest of Idaho, 2017.

Cancer type	Sex	Rate in Bonneville County	Adjusted Rate in Bonneville County	Rate for remainder of Idaho
Thyroid	Total	28.2	30.7	14.2
	Male	16.0	17.8	7.4
	Female	40.3	43.5	21.0

Table notes: Rates are expressed as the number of cases per 100,000 persons per year (person-years). Rates are expressed as the number of cases per 100,000 persons per year (person-years). Adjusted rates are age and sex-adjusted incidence rates for the county using the remainder of the state as standard. Data from Factsheet for the Cancer Data Registry of Idaho, Idaho Hospital Association. Bonneville County Cancer Profile. Cancer Incidence 2013-2017. https://www.idcancer.org/ContentFiles/special/CountyProfiles/BONNEVILLE.pdf

Radiation exposure to the head and neck in childhood is a well-known risk factor for thyroid cancer, according to the CDRI report. But monitoring of external dose levels by Department of Energy environmental monitoring programs doesn't seem to indicate higher levels in Idaho Falls.

Overall cancer incidence rates were not higher in Bonneville County compared to the rest of the state. But the incidence rates of several types of cancer were higher in Bonneville County. [2] There is higher incidence of brain and other central nervous system (CNS) non-malignant conditions, higher breast cancer incidence for males, higher testis cancer incidence, higher ovary cancer incidence, higher melanoma incidence and higher myeloma incidence. Both leukemia and non-Hodgkin lymphoma incidence adjusted rates are higher than the remainder of the state. Adjusted rates are based on age and sex-specific rates for the county, using the remainder of the state as the standard.

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[1] C. J. Johnson, B. M. Morawski, R. K., Rycroft, Cancer Data Registry of Idaho (CDRI), Boise Idaho, Annual Report of the Cancer Data Registry of Idaho, *Cancer in Idaho – 2017*, December 2019. https://www.idcancer.org/ContentFiles/AnnualReports/Cancer%20in%20Idaho%202017.pdf

[2] Factsheet for the Cancer Data Registry of Idaho, Idaho Hospital Association. Bonneville County Cancer Profile. Cancer Incidence 2013-2017. https://www.idcancer.org/ContentFiles/special/CountyProfiles/BONNEVILLE.pdf

Radiation monitoring data for Idaho Falls, Boise and Seattle, three cities in U.S. Environmental Protection Agency Region 10 that have EPA RadNet monitoring, show roughly equivalent iodine-131 in drinking water from 2000 to 2010; however, the largest iodine-131 releases were in the 1950s and 1960s, before EPA's RadNet.

Nevada weapons testing and nuclear weapons testing outside the continental U.S. by the U.S., France, China and other countries released iodine-131 as well as other radionuclides. According the U.S. studies, Nevada weapons testing produced higher thyroid doses than global fallout, especially to children. [3] The studies summarized by Steven L. Simon and others, however, do not depict higher global or Nevada weapons testing fallout for Bonneville county compared with the rest of the state of Idaho.

At the request of Idaho's Governor Cecil Andrus, the Department of Energy report issued in 1991, *INEL Historical Dose Evaluation*, [4] that estimated the radiological doses to the public from estimated airborne radionuclide releases from the Idaho National Laboratory from 1952 to 1989. The doses from the INL were estimated to be low, in the millirem. But, many of the radiological releases are known to have been underestimated and not collaborated with environmental monitoring. Thyroid doses to infants due to iodine-131, in the 1950s, caused the highest organ dose.

The article about weapons testing fallout by Simon and others discusses several radionuclides that contribute to thyroid dose. For internal thyroid dose, they point out that for Nevada weapons testing, the largest contribution came from iodine-131 with smaller contributions from cesium-136, cesium-137, ruthenium-106, strontium-89, tellurium/iodine-132, and iodine-133. For global fallout, the largest internal thyroid dose is also from iodine-131, but the other contributors are carbon-14, cesium-137, strontium-90, and tritium.

For external dose to the thyroid, the highest contributing radionuclides were considered to be from barium/lanthanum-140, zirconium/niobium-95, and tellurium/iodine-132. From global fallout, the highest external dose to the thyroid came from cesium-137 and zirconium/niobium-95.

The U.S. studies of weapons testing fallout did not take into consideration additional radiological exposures from the Idaho National Laboratory. The *INEL Historical Dose Evaluation* may have underestimated the total curies of iodine-131 released by the INL, underestimated other contributors such as the tritium, cesium-137, ruthenium-106, zirconium/niobium-95 and other radionuclides as well.

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[3] Steven L. Simon et al., *American Scientis*t, "Fallout from Nuclear Weapons Tests and Cancer Risks – Exposures 50 years ago still have health implications today that will continue into the future," 2006.

[4] US Department of Energy Idaho Operations Office, "Idaho National Engineering Laboratory Historical Dose Evaluation," DOE-ID-12119, August 1991. Volumes 1 and 2 can be found at https://www.iaea.org/inis/inis-collection/index.html

Nevada weapons testing fallout is known to have caused high thyroid radiation doses, sometimes on the order of 75 rem to the thyroid, [5] so the estimated INL doses based on the *INEL Historical Dose Evaluation* that were a thousandth of those doses, a few millirem, would not have been expected to cause the high rate of thyroid cancer in Bonneville county, where the largest city is Idaho Falls. The fact that Idaho Falls does have such high thyroid cancer rates, even in 2017, when Canyon County, Idaho, known to be hard hit by Nevada weapons testing fallout does not have high rates of thyroid cancer now, is a bit mysterious. The cancer rates for nearly every cancer type is elevated in Canyon County compared to state averages, but not thyroid cancer. [6]

Idaho Falls had the highest concentration of tritium in EPA Region 10 between 2001 and 2010 in the continental U.S. (excluding Alaska) with tritium in drinking water of 734 picocurie/liter January 17, 2006. Idaho Falls had the highest concentration of iodine-131in drinking water in Region 10 on June 13, 2016. The highest concentration recorded in Idaho for zirconium/niobium-95 doesn't go to Idaho Falls — it actually goes to Buhl, Idaho's surface water in 1983. Answering where that zirconium/niobium-95 solves an important mystery because folks in Buhl, Idaho have long been puzzled about the source of elevated levels of radioactivity. These folks have been told for a long time that the source was from weapons testing. I think that Buhl was smoked by Nevada weapons testing, by the Idaho National Laboratory and is also the recipient of contaminated water in the Snake River Plain aquifer from past deepwell injection of fuel reprocessing rinse-out wastes and percolation pond wastes from the INL.

Figure 1 shows the 1983 wind isopleth centered at the INL's fuel reprocessing facility now known as INTEC. This wind isopleth is unusual in that it shows concentration lines reaching south of Blackfoot, all the way to Pocatello. Yet, as has been the common and unscientific practice — isopleth concentration lines are chopped off both north and south of the Idaho National Laboratory. This is apparently so folks in Dubois to the north or Rupert and Buhl south of the INL won't understand that the INL airborne radionuclides were contaminating them.

The half-life of zirconium-95 is 64 days. The zirconium-95 decays to niobium-95 which has a half-life of 35 days. Those relatively short half-lives mean that the INL is the likely source because in 1983, if the most recent significant nuclear weapons tests had been by China in 1980. After all, the U.S. banned above-ground weapons testing in 1963, right? Well, it turns out that weapons testing continued at the Nevada Test Site until 1992. The Department of Energy was active in not telling the public of the contamination, each time airborne contamination for another Nevada weapons test blew in to Idaho.

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[5] Karen Dorn Steele, *The Spokesman-Review*, "Time bombs keep going off for cancer-plagued families in Idaho who lived downwind of nuclear testing in the 1950s," October 24, 2004. https://www.spokesman.com/stories/2004/oct/24/time-bombs-keep-going-off-for-cancer-plagued/

[6] A fact sheet from the Cancer Data Registry of Idaho, Idaho Hospital Association, Canyon County Cancer Profile, Cancer Incidence 2013-2017, https://www.idcancer.org/ContentFiles/special/CountyProfiles/CANYON.pdf

The Department of Energy supposedly knew when their weapons testing affected Idaho. Despite that, the *INEL Historical Dose Evaluation* review of iodine-131 in milk samples around the INL during 1981, 1982, 1983 and 1984, could not be attributed to weapons testing. Those milk samples are listed as caused by "undetermined causes" after ruling out global weapons testing and Nevada weapons testing. The Department of Energy denied that the iodine-131 found in milk near the INL in these years was from the INL.

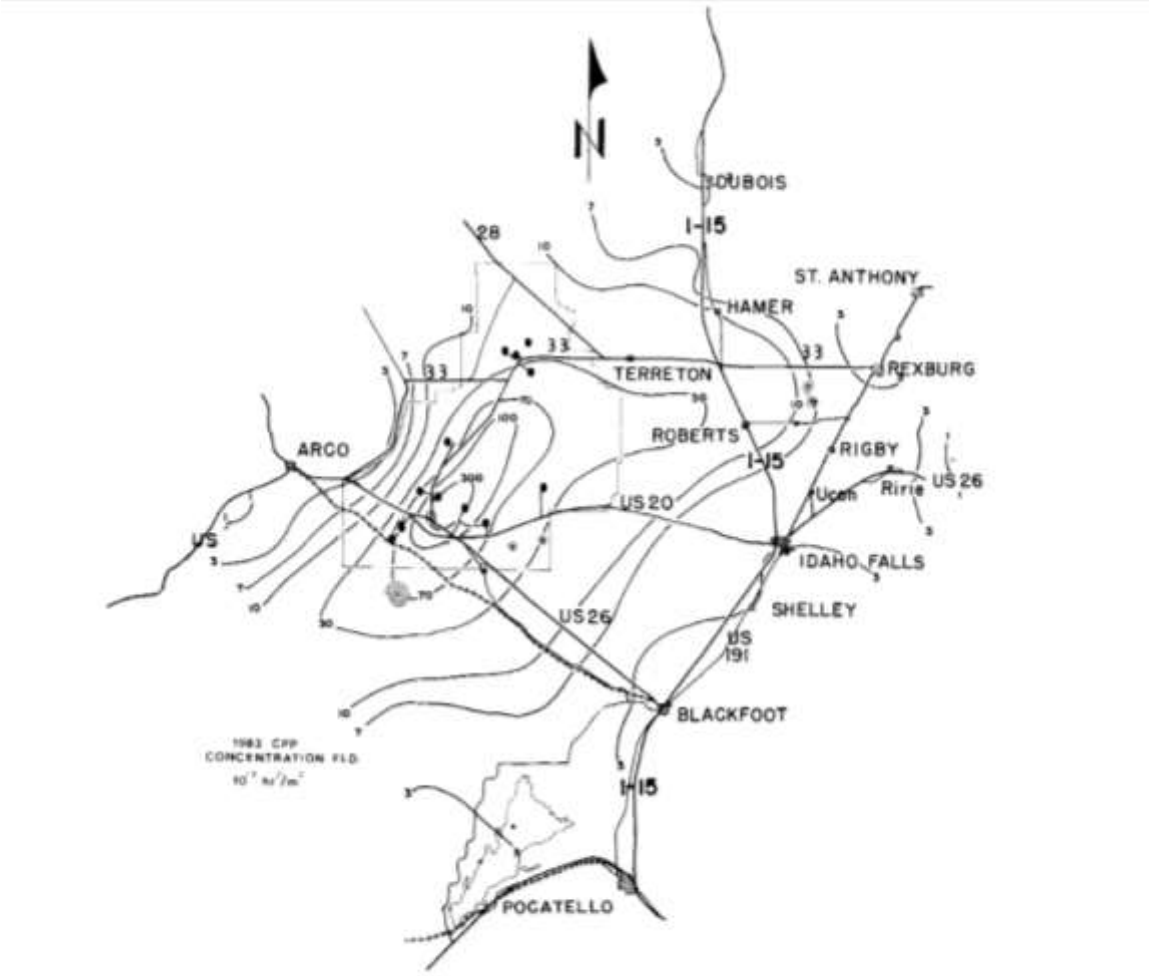

Figure 9. 1983 average mesoscale dispersion isopleths of air concentrations at ground level, normalized to unit release rate.

Figure 1. Wind isopleth depiction for the Idaho National Laboratory for 1983.

The U.S. Environmental Protection Agency had RadNet drinking water monitoring programs in Idaho Falls and Boise. July 1, 1983, the RadNet drinking water data for Idaho Falls was more than 40 times the average value, at 41.7 pCi/L when the Region 10 average was 0.739 pCi/L. The concentration of gross alpha in drinking water in Boise on July 1, 1983 was 0.34 pCi/L.

Now, you may be wondering why Idaho Falls drinking water radionuclides would be elevated because the aquifer does not flow from the INL to Idaho Falls. The Snake River Plain Aquifer underneath the INL flows downgradient and generally southward. Idaho Falls is east of

the INL. It appears that when radionuclides are airborne, they are breathed into drinking water tanks and can also land on surface water. Water wells actually breathe — my Dad remembers a well in Arco, Idaho that would whistle when the barometric pressure changed.

The mysterious levels of iodine-131 in milk sampled by the INL from 1981 to 1984 described in Appendix E of the *INEL Historical Dose Evaluation* appears to me to be from fuel reprocessing and/or calcining at the chemical processing plant now called INTEC in late 1982 and 1983, despite the denial that iodine-131 was released from the INL in those years. [7] [8] Iodine-131 is released from fuel reprocessing, fuel melt experiments or the fissioning in nuclear weapon's tests. The short half-life of 8.0252 days for iodine-131, however, discounts the possibility that the I-131 came from weapons testing fallout. The I-131 could be released if nuclear fuel, such as from the Advanced Test Reactor was processed at the INL in those years near 1983. Still, there was plenty of weapons testing releasing radionuclides to the wind from the Nevada Test Site even in 1983. See Table 2 for selected highlights of radiological events.

Table 2. Brief timeline of selected world-wide radiological events, with a focus on the northwestern United States.

Chronology	Radiological Event
1943-1957 and to the present	Hanford plutonium production and "Green Runs" in 1949 intentionally releasing thousands of curies of iodine-131, this period (1943-1957) is acknowledged to have large off-site radiological releases from nuclear reactor operations and plutonium processing. Radiological releases from Hanford continue.
1945	Trinity Test at Alamogordo, New Mexico
1945-1955	Approximately 80 above ground nuclear blasts conducted by the U.S., the Soviet Union, and Great Britain.
1949 to the present	Inception of the Idaho National Laboratory in 1949 as the National Reactor Testing Station. Air and groundwater contamination when nuclear operations commencing in 1952. Radiological contamination going offsite from reactor operation, spent fuel reprocessing, spent fuel storage, radioactive waste burial, nuclear tests and accidents, liquid storage of High-Level Waste, pyroprocessing of spent fuel, and releases of radionuclides for human testing and now for training purposes.
1952-1991	Nuclear fuel reprocessing at the Idaho National Laboratory
1956 – 1958	Approximately 180 above ground nuclear blasts by the U.S. the Soviet Union and Great Britain.
1957-1963	Idaho National Laboratory (National Reactor Testing Station) RaLa Runs at nuclear fuel reprocessing chemical plant
1958	Great Britain conducts its last test.
1960	France conducts its first three tests.

[7] Department of Energy, Idaho Operations Office, *1982 Environmental Monitoring Program Report for Idaho National Engineering Laboratory*, DOE/ID-12082(82), 1983. https://inldigitallibrary.inl.gov/PRR/92266.pdf

[8] Department of Energy, Idaho Operations Office, *1983 Environmental Monitoring Program Report for Idaho National Engineering Laboratory*, DOE/ID-12082(83), 1984. https://inldigitallibrary.inl.gov/PRR/92267.pdf

1961	Stationary Low-power Reactor (SL-1) prompt critical excursion destroys reactor at the Idaho National Laboratory
1961-1962	Approximately 100 above ground nuclear blasts by the U.S. and the Soviet Union.
1962	Sedan nuclear test for plowshares at the Nevada Test Site, a shallow test with a high amount of fallout. The test was to demonstrate the use of nuclear explosions to excavate earth and rock. The 104 kiloton TNT equivalent blast released 880,000 curies of iodine-131. It released beryllium-7, cobalt-60, manganese-54, and ruthenium-106 among other radionuclides.
1963-2003	Liquid waste from nuclear fuel reprocessing at the INL is calcined at the Waste Calcining Facility from 1963 to 1981 and at the New Waste Calcining Facility from 1982 to 2003.
1963	Above-ground partial testing ban
1965-1967	Nine above ground nuclear blasts by France and China
1968-1970	Three above ground nuclear blasts by China
1971-1973	Seventeen above ground nuclear blasts by China and France
1974	Seven above ground nuclear blasts by China and France
1976-1978	Six above ground nuclear blasts by China
1979	Three Mile Island nuclear plant core melt
1980	China conducts its last above ground nuclear blast. France nuclear plant has a fuel rupture with some off-site release. Here the U.S. EPA makes it sound like nuclear weapons tested ended in 1980, see https://www.epa.gov/radnet/history-radnet But nuclear weapons testing did not end in 1980, as air emissions were released by "underground" testing at the Nevada Test Site until 1992 and testing, world wide continued through 1998. See DOE/NV-209, December 1994 at https://fas.org/nuke/guide/usa/nuclear/usnuctests.htm
1986	Chernobyl nuclear plant explosion and major release of radionuclides from the Soviet Union nuclear power plant
1999	Japan Tokaimura nuclear fuel processing facility
2000	Cerro Grande wildfire near Los Alamos National Laboratory in New Mexico, and also wildfire at Hanford in Washington State. Also a fire at the INL near the Advanced Test Reactor
2011	Fukushima Daiichi Nuclear Power Plant in Japan meltdown of several units with extremely high release of radionuclides to air and Pacific Ocean.
2018	Four transuranic waste drums at the Idaho National Laboratory overpressurize, ejecting waste contents and smoldering at elevated temperature, and damage fabric enclosure inner lining
2018	US Ecology Grandview explosion in waste mixing trough. EPA RadNet blackout for several weeks immediately following the explosion
2019	Sheep fire burns 112,106 acres at the Idaho National Laboratory, no details are disclosed yet regarding the radiological releases.

The Department of Energy's milk monitoring programs meant that they had to admit weapons testing or reactor accidents did release radioactive iodine-131. It was common practice for the Atomic Energy Commission, the Department of Energy's predecessor, to report weapons testing releases of iodine-131 but omit discussing the release of all of the other radionuclides released. It is important to understand that many other health-harming radionuclides are typically released along with the iodine-131 including fission products such as cesium-137 and strontium-90, radionuclides formed by neutron capture during the fissioning including transuranic radionuclides such as plutonium, neptunium and curium, and the unfissioned uranium and plutonium used in the nuclear weapon.

The Department of Energy's monitoring reports do not list Zr/Nb-95 as being detected in 1982 and 1983. But these DOE INL environmental monitoring reports do acknowledge various radionuclides that are prominent in highly enriched in uranium-235, high burnup fuels commonly used at the INL such as cerium-144, ruthenium-106, antimony-125, and cesium-134. The levels of airborne gross beta at INTEC were still far higher than any other facility at the INL in 1985. Levels of radioactivity monitored by the Oregon State Health Division did not indicate weapons fallout in 1982 and 1983 but would not rule out air emissions from Nevada underground weapons testing reaching southeast Idaho. [9]

Whatever facility or multiple facilities from the INL released radionuclides in 1982 and 1983, high-enriched U-235 was detected in drinking water in Idaho Falls. There was also record setting concentrations of zinc-65 (half-life 243.66 day) in Idaho Falls drinking water, at 10 pCi/L in 1983, and record levels of ruthenium-106 (half-life 1.0186 year) in 1982 in Idaho Falls drinking water, at 8 pCi/L. See Table 3.

There are many interesting things about the RadNet data for Idaho Falls drinking water from 1978 to 2019. While fallout from Nevada weapons testing, acknowledged to have been high in thyroid cancer-causing iodine-131 was limited to below-ground testing after 1963, iodine-131 and other radionuclides were released well into the 1980s to the communities around the Idaho National Laboratory. I suspect that this has a role in the high rate of thyroid cancer in Idaho Falls.

In Idaho Falls, while the average tritium concentrations have decreased to an average of 12.6 pCi/L, the tritium concentration spikes in drinking water, like the 734 pCi/L in 2006, have occurred. And the state and Department of Energy environmental monitoring programs have not acknowledged that this occurred in their environmental monitoring programs. The State of Idaho environmental monitoring program appears to be designed to mimic the inadequate Department of Energy program. While tritium levels have been decreasing since the end of nuclear weapons testing, background levels of tritium are often inflated. The overall average for the U.S. was 54.1 pCi/L for 2001 to 2010, as noted by John Doroski in "Tritium – The "Real Background." [10]

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[9] George L. Toombs et al., Oregon State Health Division, *Environmental Radiation Surveillance Program, "Environmental Radiological Surveillance Report on Oregon Surface Waters 1961-1983*.

[10] John Doroski, "Tritium – The 'Real Background,'" RadNet Drinking Water, 2001-2010, What is the real background? http://hps.ne.uiuc.edu/rets-remp/PastWorkshops/2011/presentations/8A-Tritium%20-%20What%20is%20the%20real%20background.pdf

Table 3. Summary of selected RadNet data for drinking water in Idaho Falls, pCi/L.

Radionuclide	1978-1988 Min-Max (Average)	1989-1999 Min-Max (Average)	2000-2010 Min-Max (Average)	2011-2019 Min-Max (Average)
Tritium (12.32 yr)	100 to 700 (279 pCi/L)	0 to 500 (130 pCi/L)	0 to 734 (52.6 pCi/L) Maximum in 2006	0 to 171 (12.6 pCi/L)
Ruthenium-106 (half-life 1.01 yr)	2 positive values out of 10 samples, 8 ± 20 1982 1 ± 20 1983	One value, -6 ± 20	No data	No data
Zinc-65 (243.66 day)	5 positive values out of 10 samples, 10 ± 7.1 on July 1, 1983	1 sample 5.9 ± 7.1 on July 1, 1989	No data	No data
Zirconium/Niobium-95 (64 day/35 day)	0 to 1.7 0.5 pCi/L on July 1, 1982 and 0.4 pCi/L on July 1, 1983 1.1 pCi/L on July 1, 1984	1 sample -0.5 ± 3.5 on July 1, 1989	No data	No data
Gross Alpha	0 to **41.7** (4.59 pCi/L) Maximum in 1983	0.1 to 4.1 (1.52 pCi/L)	0 to 2.8 (1.06 pCi/L)	0 to 2.3 (1.11 pCi/L)
Gross Beta	2 to **22.4** (4.94) Maximum in 1983	2.48 to 4.51 (3.5 pCi/L)	1.5 to 5.9 (3.25 pCi/L)	1.7 to 6 (4.24 pCi/L) 6 pCi/L in 2014 and 2015
Uranium-235 (half-life 700 million years)	0.0207 to 0.183 (0.0549 pCi/L)	0.0212 to 0.027 (0.0241 pCi/L)	0.015 to 0.033 (0.0217 pCi/L)	1 sample 0.093 pCi/L on Dec 31, 2014
U-235/U-238	0.183/0.596 = 0.307 (1979) 0.027/0.209 = 0.129 (1983)	0.027/0.306 = 0.088 (1997)	0.033/0.0889 = 0.0889	0.093/0.57 = 0.163 (2014)

Table notes: The ratio of U-235 to U-238, by activity, would be 0.047 or 4.7 percent. The corresponding U-238 values were used to calculate U-235 to U-238 ratios and all interval maximums were enriched in U-235, from 8.8 percent to 30.7 percent. Radioactive decay chains and half-lives can be found at https://periodictable.com sponsored by Wolfram Research.

In 1983, there were elevated levels of rather short-lived radionuclides and very high levels of gross alpha and gross beta concentrations in Idaho Falls drinking water. The INL and the Department of Energy do not acknowledge these in their environmental monitoring programs, nor does the *INEL Historical Dose Evaluation.* The fact that certain detected radionuclides were short-lived means they were unlikely to have been from past nuclear weapons testing fallout.

The data show the proportion of uranium-235 to uranium-238 is far above the natural ratio of 0.047 or 4.7 percent. Now that makes for "highly enriched" coffee in Idaho Falls.

Uranium-235 could be included in weapons testing fallout. It now appears that the recipe for Nevada weapons tests was quite variable concerning the amount of uranium-238, uranium-235, plutonium-239 and plutonium-240. But, in 1982 and 1983, the detection of short-lived radionuclides including tritium, zirconium/niobium-95, cesium-134, cerium-144 and ruthenium-106 indicate fresh fission products for the INL rather than weapons testing fallout.

I did not include the barium-140, in surface water data for Idaho and Oregon, which appear to be biased heavily toward negative numbers. But the short 12.75-day half-life of Barium-140 having a maximum value in 1982 also appears to be from the INL and not from 1980 weapons testing by China.

To summarize, key points from this article:

- the *INEL Historical Dose Evaluation* claims that the radiation doses to the public from 1952 to 1989 were very low, yet the study underestimated or failed to disclose the actual radiological releases from the Idaho National Laboratory. The selected identified radionuclides are inconsistent and incomplete in many cases. Plutonium, curium, and uranium is usually not reported, yet was released.
- Despite the very low radiation doses published by the Department of Energy, cancer rates for citizens living near the INL are elevated above state average levels, including elevated thyroid cancer rates in Bonneville in 2017 (and Butte, Bingham, Madison Counties).
- Airborne releases from the INL blow far and wide across southeast Idaho, with the spent nuclear fuel reprocessing stack or calcine releases spreading radionuclides detected in Idaho Falls and Buhl, Idaho which were included in some EPA RadNet monitoring. (The Department of Energy's depiction of wind isopleths often were unscientifically truncated so that the contamination concentration wind isopleths did not show how far to the south the INL's contamination spreads.)
- While some radiological releases have a decreasing trend since the 1980s like tritium levels from weapons testing, the radiological releases at the INL have been ramping up as the RadNet data show over the last 20 years for gross alpha, gross beta and uranium-235. And the INL releases are slated to increase 170-fold for future planned activities. [11]

[11] The latest change to the Idaho Settlement Agreement in November 2019 agreement ***requires*** the DOE to "treat all Sodium Bonded EBR II Driver Fuel Pins into product material for High Assay Low Enriched Uranium

Additional Review of the Cancer Rates in the Cancer Data Registry of Idaho

The forty-first annual report of the Cancer Data Registry of Idaho (CDRI) was issued in December 2019 for the year 2017. [12] I took a look at the cancer rates near the INL in the February/March newsletter, and here I continue to look at the cancer registry report.

Bonneville County has very high thyroid cancer rates. Now let's look at Bingham and Madison county. This is interesting: Madison County has lower cancer rates that the state average for just about everything — except thyroid cancer, the adjusted rate. Madison County has double the state average thyroid rate. Bingham County also has about double the state average thyroid cancer rate. Bingham County also has elevated rates of colorectal, Hodgkin Lymphoma, kidney, liver, myeloma, non-Hodgkin Lymphoma, ovary, pancreas, stomach, and male childhood cancer. Butte County, as noted last in last month's article has three times the state average thyroid cancer rate and many other grossly elevated cancer rates. [13]

Bingham County receives a lot of airborne radionuclides from the Idaho National Laboratory: americium-241, plutonium-238, plutonium-239 and plutonium-240, strontium-90 and cesium-137 are commonly detected in air filters for Blackfoot. The INL environmental monitoring reports like to refer to Blackfoot as a distant site, but the fallout or resuspension of radionuclides in soil in the Blackfoot area is from INL historical fuel reprocessing, ongoing emissions from INL's INTEC and other facilities and from the burial grounds at INL now called the Radioactive Waste Management Complex. Folks in Mooreland noticed the elevated cancers year ago, but official investigations denied the levels and pervasiveness of the radionuclide contamination. Bone-seeking radionuclides prevalent in the Blackfoot area include those identified by INL monitoring and those ignored by INL environmental monitoring such as uranium and thorium levels that are elevated due to reactor or weapons fuel material being released as well as reactor-made materials such as uranium-236, uranium-233 and uranium-232. The uranium-236 and uranium-232 feed the thorium decay series associated with naturally-occurring Th-232. Soil sampling conducted by Department of Energy environmental monitoring

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(HALEU)." Idaho required DOE to start within 30 days of signing the agreement and treat at least 165 lbs heavy metal on a 3-year rolling average and DOE must complete the HALEU treatment by December 31, 2028. This gift to the Department of Energy, allowing it to pollute Idaho skies with this HALEU treatment at the INL's Fuel Conditioning Facility. Treatment of sodium bearing waste and the reckless release of radionuclides at the INL's expanded test range will be greatly increasing the radionuclide releases from the INL, to an already cancer-ridden population.

[12] C. J. Johnson, B. M. Morawski, R. K., Rycroft, Cancer Data Registry of Idaho (CDRI), Boise Idaho, Annual Report of the Cancer Data Registry of Idaho, *Cancer in Idaho – 2017*, December 2019. https://www.idcancer.org/ContentFiles/AnnualReports/Cancer%20in%20Idaho%202017.pdf

[13] A fact sheet from the Cancer Data Registry of Idaho, Idaho Hospital Association, Cancer Incidence 2013-2017, see Bingham, Butte and Madison Counties at https://www.idcancer.org/ContentFiles/special/CountyProfiles/BINGHAM.pdf https://www.idcancer.org/ContentFiles/special/CountyProfiles/BUTTE.pdf and https://www.idcancer.org/ContentFiles/special/CountyProfiles/MADISON.pdf

won't disclose were soil samples are taken and then they mix the samples for a composite sample result. No one wants the stigma of knowing what's really in their soil.

Now we take a look at the cancer rates in Gooding County, Idaho, which is closer to the Idaho National Laboratory than Buhl, Idaho. Gooding is the recipient not only of airborne radiological contamination from the INL but also hexavalent chromium and radionuclide contamination in the Snake River Plain aquifer from deepwell injection of contaminants at the INL. Rinsing out the piping at the INL's chemical spent fuel reprocessing plant at INTEC and deepwell injection into the aquifer continued until 1984. Gooding County cancer rates are elevated about the state average for cancer overall, bladder, colorectal, esophageal, Hodgkin Lymphoma, kidney, larynx, leukemia, liver, lung, myeloma, non-Hodgkin Lymphoma, oral, stomach, testis, thyroid, and male childhood cancers. [14]

Given the elevated cancer rates around the Idaho National Laboratory now, think about the proposed and now occurring elevated levels of radionuclide emissions. The INL's deliberate and health-harming radiological releases to the environment are already increasing by a factor of more than 170, for its High-Assay Low Enriched Uranium (HALEU) processing at the Materials and Fuels Complex. See my uppercase and bold additions to Table 4 comments regarding the unreliability of the estimated air emissions data.

Table 4. Estimated annual air pathway dose (mrem) from normal operations to the maximally exposed offsite individual from proposed projects, including the estimated dose from expanding capabilities at the Ranges based on DOE/EA-2063.

Current and Reasonably Foreseeable Future Action	**Estimated Annual Air Pathway Dose (mrem)**
National Security Test Range	0.04[e]
Radiological Response Training Range (North Test Range)	0.048[d]
Radiological Response Training Range (South Test Range)	0.00034[a]
HALEU Fuel Production (DOE-ID, 2019)	1.6[a]
Integrated Waste Treatment Unit (ICP/EXT-05-01116)	0.0746[h]
New DOE Remote-Handled LLW Disposal Facility (DOE/ID 2018)	0.0074[a]
Recapitalization of Infrastructure Supporting Naval Spent Nuclear Fuel Handling (DOE/EIS 2016)	0.0006[c]
TREAT (DOE/EA 2014)	0.0011[a]
DOE Idaho Spent Fuel Facility (NRC, 2004)	0.000063[a]
Plutonium-238 Production for Radioisotope Power Systems (DOE/EIS 2013)	0.00000026[b]

[14] A fact sheet from the Cancer Data Registry of Idaho, Idaho Hospital Association, Cancer Incidence 2013-2017, see Bingham, Butte and Madison Counties at https://www.idcancer.org/ContentFiles/special/CountyProfiles/GOODING.pdf

Total of Reasonably Foreseeable Future Actions on the INL Site	1.77[g]
Current (2018) Annual Estimated INL Emissions (DOE2019a)	0.0102[f]
Total of Current and Reasonably Foreseeable Future Actions on the INL Site [**DOE WOULD INCREASE INL'S AIRBORNE RELEASES BY OVER 170 TIMES**]	1.78[g]

Table notes:

a. Dose calculated at Frenchman's Cabin, typically INL's MEI for annual NESHAP evaluation.

b. Receptor location is not clear. Conservatively assumed at Frenchman's Cabin.

c. Dose calculated at INL boundary northwest of Naval Reactor Facility. Dose at Frenchman' Cabin likely much lower.

d. Dose calculated at INL boundary northeast of Specific Manufacturing Capability. Dose at Frenchman's Cabin likely much lower.

e. Sum of doses from New Explosive Test Area and Radiological Training Pad calculated at separate locations northeast of MFC near Mud Lake. **Dose at Frenchman's Cabin likely much lower.**

PLEASE NOTE THAT THE PUBLIC AT MUD LAKE IS CLOSER TO THE RELEASE THAN TO FRENCHMAN'S CABIN.

f. Dose at MEI location (Frenchman's Cabin) from 2018 INL emissions (DOE 2019a). The 10-year (2008 through 2017) average dose is 0.05 mrem/year.

PLEASE NOTE THAT MANY RADIOLOGICAL RELEASES ARE IGNORED AND NOT INCLUDED IN THE RELEASE ESTIMATES IN NESHAPS REPORTING.

g. This total represents air impact from current and reasonably foreseeable future actions at INL. It conservatively assumes the dose from each facility was calculated at the same location (Frenchman's Cabin), which they were not.

h. Receptor location unknown.

Department of Defense Prototype "Microreactors" would create a "dirty bomb" target, releasing a million curies to environment

The Department of Defense requested public comments regarding its terrible idea to create a 1 to 10 megawatt-electric prototype "microreactor" at the Idaho National Laboratory. The concept is to develop a gas-cooled reactor that can be deployed for electrical power generation. The nuclear fuel would use high-assay low enriched uranium (HALEU) which is higher enriched in uranium-235 than commercial power reactors. Higher enrichment allows for higher burnup and this means that more fission products are released under accident conditions.

The proposed tristructural isotropic (TRISO) fuel is ceramic coated and able to withstand high temperatures. Yet, these reactors are anything but "micro" in terms of the potential radiological release, and could release a few million curies because of an accident or intentional sabotage or terrorist act.

The Department of Defense needs to step back and find non-nuclear ways of generating electricity that won't contaminate communities in the U.S. or around the globe. Currently, they want to conduct an Environmental Impact Statement that does not include non-nuclear alternatives.

The project alternatives must include developing a system of batteries, solar, wind and/or diesel fuel combinations. These would not provide a very attractive terrorism target, would not shorten the lives of everyone working near the microreactor and would not pose the accident risks that would contaminate from 100 to 1000 square miles. Not to develop more affordable, effective, and safe options simply amplifies the fact that this is really a PORK project for the Idaho National Laboratory to provide it a reason for existing.

The EIS must not rely on previous environmental impact statements that presume the existence of a non-existent spent nuclear fuel (SNF) and high-level waste (HLW) repository. The Department of Energy is pretending that an SNF/HLW repository will be available soon and therefore should want to make more nuclear fuel to operate in nuclear reactors in order to make even more spent fuel. And the DOE is using the lack of a repository as an excuse for failing to prepare the SNF and HLW at the Idaho National Laboratory for shipment to a repository such as the proposed Yucca Mountain repository.

Relying on out-of-date EISs that don't represent the lack of progress toward a repository for spent nuclear fuel and high-level waste and DOE's failure to update radiological health models and standards cannot possibly achieve the stated goals of conducting NEPA analysis.

Should this EIS mention fuel reprocessing as an option, then it must include the truth about the extensive radiological contamination at West Valley, New York as well as at and around the Idaho National Laboratory. The biased and incomplete monitoring by the U.S. Geological Survey cannot be relied on as the complete basis for characterizing the aquifer contamination from the fuel reprocessing conducted at the INL because the U.S.G.S. was actively engaged in covering up the extent of groundwater contamination in southeast Idaho.

The DOE continues on a path to miss all future Idaho Settlement Agreement milestones for treating, packaging and shipping spent nuclear fuel and high-level waste out of Idaho and the prototype microreactor EIS must not hide the numerous serious failures of the Department of Energy to meet these important milestones. [15] This project will only add to the burdens Idaho citizens already have from the radiological contamination from the Idaho National Laboratory.

Consider using this attractive "dirty bomb" near a hospital. The humanitarian effort to provide electricity becomes a way to poison that community, virtually forever. The routine emissions alone may be enough for this to foster negative views of the U.S. military. Where are they going to take the spent nuclear fuel and store it, forever? Or just leave these million curies of radiotoxic material scattered around during and after a war? It's a horrible idea, one that should go the way of the nuclear jet engine aircraft that was being tested at the Idaho National Laboratory, that was cancelled in 1961.

[15] See more about Idaho's Settlement Agreement at https://www.deq.idaho.gov/inl-oversight/oversight-agreements/1995-settlement-agreement.aspx

My public comment submittal and Environmental Defense Institute's comment submittal regarding the scope of an Environmental Impact Statement for the prototype microreactor are on the EDI website. [16] [17]

The Department of Energy needs to issue a revised INEL HDE that doesn't hide so much about the radiological releases from the Idaho National Laboratory since 1952

The Stationary Low-power reactor (SL-1) that was destroyed in a prompt critical excursion when a single control rod was withdrawn too far in 1961 was a roughly 3 megawatt-thermal reactor. The fuel was highly enriched in uranium-235 and the reactor was designed to accommodate two years of operations without refueling. The fuel had operated for about its full life when the accident happened, maximizing the fission product release.

The SL-1 is in many ways is quite similar in hubris concerning the "prototype microreactor." The SL-1 was 3 megawatts-thermal and high enriched uranium-235 with high burnup. The millions of curies released from that accident smoked much of southeast Idaho from Monteview to Albion, despite Department of Energy's continued lie that only 1100 curies were released. Read more about the SL-1 accident at the Environmental Defense Institute website. [18] [19] [20]

Roughly 30 percent of the 2.5 megawatt-thermal SL-1 core was vaporized in building exhausting through a ceiling vent. The initial curie inventory of the core would have been roughly at least 2 million curies and there are more fission products in the parts of the core that melted. The Department of Energy is still claiming that the SL-1 accident released mainly iodine-131 and that the total release was only 1100 curies. In addition, the Department of Energy in the *INEL Historical Dose Evaluation* claims that no uranium, plutonium, or americium was released.

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[16] Tami Thatcher, Public Comment Submittal on the Department of Defense "Prototype Microreactor EIS Comments" on the scope of an Environmental Impact Statement for Construction and Demonstration of a Prototype Advanced Mobile Nuclear Microreactor, Docket Number DOD-2020-OS-0002, March 30, 2020. http://www.environmental-defense-institute.org/publications/PublicCommentMicroRx.pdf

[17] Chuck Broscious, Environmental Defense Institute, Comments on Scoping Warfighter Mobile Nuclear Reactor Power Generation Environmental Impact Statement, March 31, 2020. http://www.environmental-defense-institute.org/publications/EDIMicroreactor.pdf

[18] Environmental Defense Institute newsletter articles by Tami Thatcher, for December 2019: "Interesting Similarities Between the SL-1 and the Chernobyl Nuclear Accidents," Understanding Reactivity Insertions – And Why You Should Never Insert a Dollar…," and "Just Some of the Lies Told About SL-1 Accident to Coverup the Accident Cause and Consequence," at http://www.environmental-defense-institute.org/publications/News.19.Dec.pdf

[19] Environmental Defense Institute September 2019 newsletter article by Tami Thatcher: "A Comparison of the Three Mile Island Unit 2 Fuel Release Fractions to the SL-1 Derived Release Fractions," at http://www.environmental-defense-institute.org/publications/News.19.Sept.pdf

[20] Tami Thatcher, *Environmental Defense Institute*, updated 2019, "The SL-1 Accident Consequences," at http://environmental-defense-institute.org/publications/SL-1Consequences.pdf and "The Truth about the SL-1 Accident – Understanding the Reactor Excursion and Safety Problems at SL-1" at http://environmental-defense-institute.org/publications/SL-1Accident.pdf

Estimates of the fuel release fractions for the SL-1 accident performed for the Center for Disease Control implied by the Department of Energy's stated released yielded impossibly low fuel release fractions for that fuel design. [21] If the aluminum-clad fuel using in the SL-1 reactor performed that well, why isn't anyone using that design now?

The estimated releases from the SL-1 accident are provided in Table 5. The AEC grossly understated the SL-1 radiological release and the Department of Energy continues the deception which would have otherwise dominated all historical INL radiological releases.

Even now the Idaho Operations Office and their "story" about the SL-1 accident in the DOE-funded book *Proving the Principle* [22] lays the blame for the SL-1 accident on a crewman and presents incorrect information about the accident.

Table 5. SL-1 radiological release estimates.

Element	Inventory (Ci)	AEC Release Fraction, percent (Note 1)	INEL HDE Release Estimate (Ci) (Note 2)	More Probable Release Fraction	More Probable Release (Ci)
Iodine-131	18,182 Ci	0.44 percent	80 Ci	30 to 100 percent	5455 to 18,182 Ci
Cesium-137	2,941 Ci	0.017 percent	0.5 Ci	30 percent	882 Ci
Strontium-90	2,778 Ci	0.0036 percent	0.1 Ci	30 percent	833 Ci
All radionuclides	~2,000,000 Ci		1100 Ci		~1,000,000 Ci

Table Notes: 1. Risk Assessment Corporation estimated the SL-1 release fractions, based on the release estimates by the Atomic Energy Commission (AEC), now the Department of Energy. Report by Risk Assessment Corporation for Centers for Disease Control and Prevention, Department of Health and Human Services, *Final Report Identification and Prioritization of Radionuclide Releases from the Idaho National Engineering and Environmental Laboratory*, RAC Report No. 3, CDC Task Order S-2000-Final, October 2002, pages 117, 118. https://www.cdc.gov/nceh/radiation/ineel/TO5FinalReport.pdf Note 2: See *Idaho National Engineering Laboratory Historical Dose Evaluation*, DOE-ID-12119, August 1991. US Department of Energy Idaho Operations Office, Volumes 1 and 2 (and Table A-41 with SL-1 release estimates) at https://www.iaea.org/inis/inis-collection/index.html or see https://inldigitallibrary.inl.gov and Note 3: K. J. Holdren et al., Lockheed Idaho Technologies Company, *Remedial Investigation/Feasibility Study Report for Operable Units 5-05 and 6-01 (SL-1 and BORAX-1 Burial Grounds)*, INEL-95/0027, March 1995. This report has slightly different curie estimates than the RAC report, with 2954 curies of Cs-137 and 2845 curies of Sr-90. Total inventory decayed to 6 months after the SL-1 accident is 221,500 curies, which would correspond to a 10-fold higher inventory of about 2 million curie inventory at the time of the January 3, 1961 accident.

[21] Report by Risk Assessment Corporation for Centers for Disease Control and Prevention, Department of Health and Human Services, *Final Report Identification and Prioritization of Radionuclide Releases from the Idaho National Engineering and Environmental Laboratory*, RAC Report No. 3, CDC Task Order S-2000-Final, October 2002, pages 117, 118. https://www.cdc.gov/nceh/radiation/ineel/TO5FinalReport.pdf

[22] Susan Stacy, "Proving the Principle – A History of the Idaho National Engineering and Environmental laboratory, 1949-1999," Washington, D.D.: US Department of Energy. p. 148. http://www.inl.gov/publications/ and http://www.inl.gov/proving-the-principle/introduction.pdf

Radium-228 spikes in our southeast Idaho air and water and why it matters

Public drinking water programs provide some limited radiological monitoring. The monitoring programs will sample for gross alpha concentrations, and if over 15 picocuries/liter, then they will sample for the uranium concentration and also the radium-226 and radium-228 concentrations in the drinking water. Gross beta levels are less often monitored in recent years.

The public drinking water programs are apparently built upon the assumption that any uranium or thorium in the drinking water are there because of naturally-occurring uranium-238 and thorium-232. Radium-226 is the decay progeny of uranium-238. Radium-228 is the decay progeny of thorium-232. The levels of uranium-235 that are naturally occurring are assumed to be so low that there is no need to monitor the uranium-235. These are the three naturally-occurring decay series for uranium and thorium.

But there is a fourth decay series, the "neptunium" or uranium-233 series, entirely from reactor- or weapons-produced material. This is the series that americium-241 decays through. This decay series is prevalent in southeast Idaho, but is not monitored in drinking water programs, other than the level of gross alpha concentration.

The three "naturally-occurring" decay series, for uranium-238, thorium-232 and uranium-235 as well as the uranium-233 series can be elevated because of groundwater contamination or because of airborne contamination due to reactor- or weapons-produced radiological contamination. While many fission products do adhere to soil and would only leach into groundwater slowly, when airborne, these radionuclides are breathed into wells and water tanks. The radionuclides dissolve into the water and then we drink the water.

Four decay series are presented in Tables 6 through 9 below, including the reactor- or weapons-made actinides that decay through the same series:

the uranium-238 decay series known as the uranium series;

the thorium-232 decay series known as the thorium series;

the uranium-235 decay series known as the actinium series, and

the uranium-233 decay series sometimes known as the "neptunium" series.

As shown in the decay series tables, man-made actinides can decay to "natural" decay series. But natural does not mean healthy especially when the levels of decay progeny are elevated. And the experts that pretend that the decay progeny are from "natural" background are not admitting that the reason the levels of decay progeny are elevated is due to the release of radionuclides from the INL and other nuclear operations.

Many of these decay progenies are harmful to health but are not monitored because of the techniques used to perform sampling or due to a mistaken belief that since uranium is natural it does not need to be monitored. Uranium health effects depend on the solubility and the

Table 6. Uranium-238 decay series.

Californium	Cf-250 *						
Curium	Cm-246 *		Cm-242				
Americium	↓	Am-242 /^	↓				
Plutonium	Pu-242	↓	Pu-238				
Neptunium	↓	Np-238 /^	↓				
Uranium	U-238		U-234				
Protactinium	↓	Pa-234 /^	↓				
Thorium	Th-234 /^		Th-230				
Radium			Ra-226				
Radon			Rn-222				
Polonium			Po-218		Po-214		Po-210
Bismuth			↓	Bi-214 /^	↓	Bi-210 /^	↓
Lead			Pb-214 /^		Pb-210 /^		Pb-206 (stable)

Table notes: Alpha decay downward reduces the atomic mass by 4; beta decay upward diagonally to the right flips a neutron to a proton and stays at the same atomic mass. In the table, arrow symbols downward are used to show the progression of some alpha decays if there was space to show the arrow. Movement upward and to the right is shown by /^ which is a lame keyboard attempt to look like an arrow. Man-made actinides are shown in grey.
* Decay series to Cf-250 and Cm-246 not shown which include Cm-250, Pu-246, Am-236 and Bk-250.
Sources of uranium-238 include natural soil and rock sources, depleted uranium, reactor fuel melting from reactor accidents, and spent fuel reprocessing. Sources of uranium-234 decay progeny can include plutonium-238.

Table 7. Thorium-232 decay series.

Californium	Cf-252		Cf-248				
Curium	Cm-248		Cm-244				
Americium	↓		↓				
Plutonium	Pu-244		Pu-240		Pu-236		
Neptunium	↓	Np-240/^	↓		↓		
Uranium	U-240/^		U-236		U-232		
Protactinium			↓		↓		
Thorium			Th-232		Th-228		
Actinium			↓	Ac-228/^	↓		
Radium			Ra-228/^		Ra-224		
Radon					Rn-220		
Polonium					Po-216		Po-212
Bismuth					↓	Bi-212/^	↓
Lead					Pb-212/^	↓	Pb-208 (stable)
Thallium						Tl-208/^	

See table notes for Table 6. Sources of thorium-232 include natural thorium-232 in rock and soil. Plutonium-240 and uranium-236 which results from neutron capture in a reactor also decay to thorium-232. Depleted uranium can include uranium-236. The higher actinides that decay to plutonium-240 include californium-252 and -248, curium-248 and -244, plutonium-244, and neptunium-240. Notice the reactor-made U-232 that rapidly decays to thallium-208 and then lead.

Table 8. Uranium-235 decay series.

Californium	Cf-251						
Berkelium	↓	Bk-247					
Curium	Cm-247	↓	Cm-243				
Americium	↓	Am-243	↓				
Plutonium	Pu-243 /^	↓	Pu-239				
Neptunium		Np-239 /^	↓				
Uranium			U-235				
Protactinium			↓	Pa-231			
Thorium			Th-231 /^	↓	Th-227		
Actinium				Ac-227 /^	↓		
Radium				↓	Ra-223		
Francium				Fr-223 /^	↓		
Radon					Rn-219		
Polonium					Po-215		
Bismuth					↓	Bi-211 /^	
Lead					Pb-211 /^	↓	Pb-207 (stable)
Thallium						Tl-207 /^	

See table notes for Table 6. Sources of uranium-235 include natural uranium in rock and soil. The proportion of U-235 to U-238 can be altered by reactor-made or weapons-related releases. Plutonium-239 also decays to uranium-235 and higher actinides (californium, curium, americium and neptunium) are shown. Dispersion of reactor fuel from reactor accidents and spent fuel reprocessing can spread uranium-235 in the environment.

Table 9. Uranium-233 (or sometimes called the neptunium) decay series.

Californium	Cf-241					
Curium	Cm-245					
Americium	↓	Am-241				
Plutonium	Pu-241 /^	↓				
Neptunium		Np-237				
Uranium		↓	U-233			
Protactinium		Pa-233 /^	↓			
Thorium			Th-229			
Actinium			↓	Ac-225		
Radium			Ra-225 /^	↓		
Francium				Fr-221		
Radon				↓		
Astatine				At-217		
Polonium				↓	Po-213	
Bismuth				Bi-213 /^	↓	Bi-209
Lead				↓	Pb-209 /^	↓
Thallium				Tl-209 /^		Tl-205

See table notes for Table 6. Uranium-233 is not naturally occurring. This weapons fissile material can only be produced in a reactor or by the higher actinide decays shown including plutonium-241 and americium-241 decay. Higher actinides (californium, curium, americium and neptunium) are shown. Uranium-233 can and has been used in nuclear weapons testing. Its dispersion can also result from various weapons production and separations processes. Disposal of americium-241 following plutonium purification may be a significant source. It can also result from spent fuel reprocessing particularly of high enriched uranium fuel because of the high buildup of neptunium-237 in HEU reactor operations and by neutron capture reaction of U-235's protactinium-231.

concentration and health studies of miners are not necessarily exposed to comparable chemical forms of uranium.

Inhalation of Radium-228 from the thorium-232 decay series is about three times more harmful than radium-226. Ra-228 decays to actinium-228 which has a 0.97 MeV gamma and must go through many other decays before becoming nonradioactive lead-208. Ra-228 is more cancer causing than any other plutonium or uranium radionuclide. Yet, the Department of Energy environmental monitoring programs are ignoring radium-228, thallium-208, and other INL contaminations.

Table 10. Lifetime cancer mortality risk for radium, plutonium and uranium, selected isotopes prevalent in southeast Idaho.

Radionuclide	Inhalation (per picocurie)	Ingestion (per picocurie)
Radium-226	2.4E-8	**2.9E-9**
Radium-228	**9.0E-8**	1.3E-9
Plutonium-238	3.0E-8	1.3E-10
Plutonium-239	2.9E-8	1.3E-10
Plutonium-240	2.9E-8	1.3E-10
Americium-241	2.4E-8	9.5E-11
Neptunium-237	1.5E-8	5.8E-11
Curium-244	2.3E-8	7.5E-11
Uranium-232	1.8E-8	2.7E-10
Uranium-233	1.1E-8	6.3E-11
Uranium-234	1.1E-8	6.1E-11
Uranium-235	9.5E-9	6.2E-11
Uranium-236	9.9E-9	5.8E-11
Uranium-238	8.8E-9	7.5E-11
Protactinium-231	2.5E-7	6.0E-10

Uranium, including depleted uranium, persists in the environment essentially forever and causes illness, cancer and increased risk of birth defects. Gulf war veterans found this out as their babies were born with missing fingers and arms. See our 2017 EDI report about radiological and

chemical exposures at the INL. [23] The health harm caused by inhalation or ingestion of depleted uranium includes illness and increased risk of birth defects. [24] [25]

Actinides above uranium and thorium are created by neutron capture during reactor operations or weapons testing and include neptunium, plutonium, americium, curium and californium. The four decay series above show the man-made actinides that decay through the same series, see Tables 6 through 9, boxes highlighted in grey. For example, plutonium-238 decays to uranium-234 of the uranium-238 decay series. Plutonium-239 decays to uranium-235 of the uranium-235 decay series. Uranium-236 is a reactor-made radionuclide that decays to thorium-232. The entire neptunium (or uranium-233) series is manmade.

The decay series depict alpha decay as progressing downward and reducing the atomic mass by 4. Beta decay by electron emission is depicted as progressing upward diagonally to the right. Beta decay flips a neutron into a proton and stays at the same atomic mass. Isotopes of the same chemical element have the same number of protons but can have variable numbers of neutrons and variable atomic mass. The half-lives of the various radionuclides range from millions or billions of years to milli-seconds.

Along with alpha and beta decays at various energy levels, gamma photon emissions of various energy levels can also occur which can be detected by gamma spectrometry.

So, while uranium, thorium and plutonium are thought of primarily as alpha particle emitters, gamma radiation is also usually emitted. The decay progeny may emit beta particles rather than alpha particles. The levels of gamma radiation, in kiloelectron volts (keV) or megaelectron volts (MeV), provide a profile that can often be used to identify the radionuclide using gamma spectrometry. Some radionuclides have prominent high energy gamma's with high abundance, so they are relatively easy to identify. Others, such as have very low energy gammas, or gammas that don't have prominent peaks relative to the other radioactive gammas in the environment.

Weak or low energy gamma emissions require less shielding than higher energy gamma emissions. Uranium decay progeny of Th-231, Th-234 and Pa-234, all beta emitters, have high specific activity in curies per gram that require some protection of workers. Lead-214 and thallium-208 have high energy gamma rays, 1.76 MeV and 2.62 MeV.

Sources of uranium-238 include natural soil and rock sources, mill tailings, depleted uranium, reactor fuel melting from reactor accidents, and spent fuel reprocessing. Sources of uranium-234 decay progeny can include man-made plutonium-238 that is present in various materials and processes at the INL as well as weapons testing fallout.

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[23] Tami Thatcher, Environmental Defense Institute, *Radiological and Chemical Exposures at the INL That Workers May Not Have Known About*, April 2017. http://www.environmental-defense-institute.org/publications/Radchemreport.pdf

[24] Rosalie Bertell, International Journal of Health Services, "Depleted Uranium: All the Questions About DU and Gulf War Syndrome Are Not Yet Answered," 2006. p. 514 https://ntp.niehs.nih.gov/ntp/roc/nominations/2012/publiccomm/bertellattachmentohw.pdf

[25] Depleted Uranium Education Project, *Depleted Uranium Metal of Dishonor How the Pentagon Radiates Soldiers & Civilians with DU Weapons*, 1997. ISBN:0-9656916-0-8

Sources of thorium-232 include natural thorium-232 in rock and soil. Sources of thorium-232 can also include man-made plutonium-240 and uranium-236 resulting from neutron capture in a reactor. **And importantly, reactor-made uranium-232 decays into the thorium-232 series midway, by decaying into thorium-228. Plutonium-236 decays to uranium-232, or uranium-232 can also be produced by neutron capture by protactinium-231.**

Sources of uranium-235 include natural uranium in rock and soil but are typically considered to be of small enough abundance to be ignored. But this decay series should not be ignored where enriched uranium is released to the environment. Sources of the U-235 decay series also include plutonium-239 which decays to uranium-235. Dispersion of reactor fuel from reactor accidents and spent fuel reprocessing can spread uranium-235 in the environment. Weapons testing has been conducted with varying amounts of uranium-235 as well as uranium-238. Waste water disposal from HEU spent fuel reprocessing has put uranium-236 in the Snake River Plain Aquifer. Fuel reprocessing and calcining and reactor fuel melt tests or accidents spread various radionuclides present in nuclear fuels to air and soil.

Uranium-233 is not naturally occurring. This weapon's fissile material can only be produced in a reactor or by the higher actinide decays shown including plutonium-241 and americium-241 decay. **It does not require thorium-232 in the original fuel in order to produce uranium-233.** Uranium-233 has been dispersed by its production, separation and limited use in nuclear weapons testing. Disposal of americium-241 following plutonium purification may be a significant source. It can also result from spent fuel reprocessing particularly of high enriched uranium fuel because of the high buildup of neptunium-237 and other neutron capture reactions in high enriched, high burnup reactor operations prevalent at the Idaho National Laboratory.

Higher actinides such as californium, curium, americium and neptunium may be produced using target material in nuclear reactors in order to produce weapons related materials or to produce a heat source for radiothermal generators such as plutonium-238 which is used as a power supply in spacecraft. [26] These materials have been disposed of routinely to an open-air evaporation pond at the INL's ATR Complex. These materials have not necessarily been included in required federal reporting under the National Emissions Standards (NESHAPs) because they are not monitored but only estimated. Therefore, whenever unplanned releases are occurring via escaping resin beads, for example, the emissions would be underestimated. Frankly, the NESHAPs reporting by the INL appears to lack validation and may substantially understate INL's airborne emissions of transuranics and other radionuclides.

[26] Transuranics are radionuclides often having extremely long half-lives. Many decay progeny may be created before reaching a stable, non-radioactive state. See our factsheet at http://www.environmental-defense-institute.org/publications/decayfact.pdf. See also an ANL factsheet at https://www.remm.nlm.gov/ANL-ContaminationFactSheets-All-070418.pdf

Curium-244 was reported in 25 soil samples onsite and also in offsite soil samples conducted in 1991, yet is rarely monitored. [27]

The environmental monitoring of airborne radioactivity around the Idaho National Laboratory by Department of Energy contractors tends to ignore peaks and appears to be missing weeks of data in graphs charting alpha and gamma airborne radiation levels. This can be observed for various years, but is particularly obvious in 2006. [28] Particulate matter in filters for 2006 provide instances of elevated levels of radionuclides such as plutonium-239, plutonium-238 and americium-241 in the filters along with cesium-137 and strontium-90. A high statistical bar allows denial that a "detection" of the radionuclide occurred.

Numerous "detections" were admitted in assessing filter particulate in 2006, see first quarter 2006 air monitoring at www.idahoeser.com. [29] This makes the gaps in air monitoring data particularly troubling.

The coincidence of elevated levels of airborne radioactivity seem to correspond to elevated gross alpha and gross beta levels in drinking water monitoring.

While the Department of Energy does not monitor radium-226 or radium-228, public drinking water monitoring does. The Department of Energy's monitoring programs are not explaining why high airborne radiological contamination is creating the elevated Ra-226 and/or Ra-228 concentrations in drinking water. Table 11 shows one evaluation of expected background levels of uranium, radium-226 and radium-228. The background levels of radium-226 and radium-228 were typically be considerably less than 1 pCi/L, each. But values as high as 10 pCi/L are sometimes detected in local drinking water.

When elevated levels of radium-226 are detected in drinking water, it may be from airborne reactor-made plutonium-238 and uranium-234. **When elevated levels of radium-228 are detected in drinking water, it may be from reactor-made plutonium-240 or uranium-236 that feed the thorium-232 decay series.** High levels of thallium-208 may be due either to plutonium-240 or to reactor-made uranium-232 that feeds midway into the thorium-232 decay series, and rapidly decays to thallium-208 before decaying to stable lead-208. **Why aren't the Department of Energy's environmental monitoring programs monitoring these radionuclides that have been historically and still are being released to southeast Idaho?**

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[27] S. M. Rood, G. A. Harris, and G. J. White, Idaho National Engineering Laboratory, *Background Dose Equivalent Rates and Surficial Soil Metal and Radionuclide Concentrations for the Idaho National Engineering Laboratory*, INEL-94/0250, Revision1, August 1996.

[28] Annual and quarterly environmental monitoring reports of the Idaho National Laboratory and surrounding communities is available at http://www.idahoeser.com/Publications_surveillance.htm as the Department of Energy funded and overseen Idaho National Laboratory Site Environmental Surveillance, Education, and Research Program. Some charts are edited to reduce clarity but charts using raw data show significant gaps in monitoring airborne gross alpha and gross beta the graphs available by community.

[29] Annual and quarterly environmental monitoring reports of the Idaho National Laboratory and surrounding communities http://www.idahoeser.com/Publications_surveillance.htm

Table 11. Radium-226 and radium-228 concentrations in groundwater near the INL, expected background concentrations and an example of spiking levels in groundwater encountered.

Total Uranium	Radium-226	Radium-228	Radium-224	Source
Minimum: 0.01 ug/L Maximum: 2.97 ug/L Expected: 0 to 9 ug/L, but this is inflated.	Minimum: 0.03 pCi/L Maximum: 0.096 pCi/L Expected: 0 to 0.1 pCi/L	ND Maximum: 0.618 pCi/L Expected: 0 to 0.3 pCi/L	0.33 pCi/L Maximum: 0.93 pCi/L So rarely monitored, but background levels are not known. Note that uranium-232 contamination would raise the Ra-224 without raising the Ra-228.	Golden Associates compilation of U.S.G.S. data for 5 wells, 1989-1991
Idaho Falls area, spike 1/25/2011 1.22 ug/L	Idaho Falls area, spike 1/25/2011 3.62 pCi/L	Idaho Falls area, spike 1/25/2011 10.26 pCi/L	Not monitored	PDWS, note that gross alpha was 14.17 pCi/L where normally below 3 pCi/L

Table notes: Golden Associates, for EG&G Idaho, "Assessment of Trends in Groundwater Quality at the Idaho National Engineering Laboratory," 933-1151, October 29, 1993.

Articles by Tami Thatcher for April 2020.