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Is the solution to the growing spent nuclear fuel problem as simple was giving states more legal authority?

A recent article by Geoffrey Fettus in Scientific American had a very provocative title: "Nuclear Waste is Piling Up. Here's How to Fix the Problem." [1] But while the article did discuss some relevant facts, the solution promoted was not a solution. Actually, the suggestions were more akin to rearranging the deck chairs on the Titanic.

By ignoring the technical challenges of spent fuel disposal, of long-term storage of spent fuel and the astronomical costs involved with disposal and continued repackaging of spent fuel, and the magnitude of the hazard posed to life on the planet, the article conceals the true magnitude of the problem along with giving a solution that is not a solution.

Nuclear promotors know that the current federal law, the Nuclear Waste Policy Act, 1984 and as amended, regarding consolidated interim storage required progress on a permanent repository. So nuclear promotors are seeking to grease the laws so that parking lots dumps can grow, unfettered. The Department of Energy has no program to obtain permanent disposal of spent nuclear fuel. Nor does it have credible plans for reprocessing, which is an expensive and highly polluting endeavor, that creates far higher volumes of radioactive waste overall.

States currently have hazardous waste laws and may regulate, along with the U.S. Environmental Protection Agency, operations involving chemically hazardous waste. While this waste may include radioactive material, the EPA and states do not regulate the radioactive portion of the waste. Fettus suggests changing the laws to allow states to regulate spent nuclear fuel is some sort of solution.

Who pays for the state to determine a viable disposal facility for spent nuclear fuel in their state? Even if a state regulates such a spent fuel facility, will the state provide adequate radiological monitoring? And if the spent fuel storage or disposal facility is leaking, who pays for the damage caused by migration of radioactive material from the dump? **More state regulatory authority isn't a bad idea – it just isn't a solution to the spent nuclear fuel storage and disposal problem.**

[1] Geoffrey H. Fettus, *Scientific American*, "Nuclear Waste is Piling Up. Here's How to Fix the Problem," October 18, 2023. https://www.scientificamerican.com/article/nuclear-waste-is-piling-up-heres-how-to-fix-the-problem/?utm_medium=email

The U.S. Nuclear Regulatory Commission licenses commercial nuclear reactor operations, low-level waste radioactive disposal and licenses other radioactive material facilities such as fuel enrichment facilities. States with NRC-licensed nuclear operations already can take a larger role by becoming Agreement States.

The Department of Energy conducts its reactor operations and weapons programs largely without NRC licensing. There are exceptions such as the Three Mile Island fuel debris stored at the Idaho National Laboratory in an NRC-licensed facility with the DOE as the license holder.

Disposal of radioactive waste on Department of Energy sites has long been subject to the whim of the Department of Energy and it has a long legacy of polluting air, land and water.

The nuclear industry wants to gut laws regarding storage and disposal of spent nuclear fuel, and what Fettus seems to play in to their aim. By implying that the problem of spent nuclear fuel is simply a regulatory matter that requires shuffling of regulatory authority, the article by Fettus does more harm than good. It does not address the problem of spent nuclear fuel disposal.

See the Environmental Defense Institute September and October 2023 newsletters and others for more information about the challenges of spent nuclear fuel storage and disposal.

Idaho Cleanup Project seeks to forever poison Idaho by leaving the Calcine Waste over the Snake River Plain Aquifer

Its official. The Department of Energy is planning to leave radioactive high-level radioactive waste in a highly soluble form, above the Snake River Plain Aquifer, so that seismic events, flooding events, or the passage of time can disperse this radioactive material into air and groundwater. [2]

Spent nuclear fuel from DOE research reactors and naval submarine fuel that was highly enriched in uranium-235 was reprocessed at the Idaho National Laboratory. The liquid high-level waste was then treated to create a dry waste in the Waste Calcining Facility between 1963 and 1981, and at the New Waste Calcining Facility between 1983 and 2000. Six calcined solids storage facilities (CSSF), aka, “Bin Sets,” of various designs, contain calcine waste and a seventh Bin Set remains empty, in reserve. The calcine is stored at the Idaho Nuclear Technology and Engineering Center (INTEC), formerly the “chem plant” at the INL.

The calcine also includes radioactive waste not from reprocessing such as from the extensive radioactive target processing. Newly generated radioactive liquid waste is still being added to the liquid waste now being treated by the IWTU.

The Department of Energy has now released its “Draft Basis for Section 3116 Determination for Closure of the INTEC Calcined Solids Storage Facility at the INL Site.” This document

[2] Department of Energy, Idaho Cleanup Project Citizens Advisory Board for October 2023 at https://www.energy.gov/em/icpcab/articles/icp-cab-meeting-materials-october-2023 (See Idaho Cleanup Project Calcine Disposition Project Draft CSSF 3116 Basis Document, October 25, 2023 and other presentations.)

provides a highly biased analysis to argue that their scheme is lawful because it meets Section 3116 of the "Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005" (NDAA Section 3116).

Basically, it allows DOE to reclassify the high-level waste and call it "low-level waste." And it allows this vast amount of "greater-than-Class C" radioactive waste to be unsafely stored and thus dispersed into air, soil and groundwater in Idaho. It is just a matter of time.

The Citizens Advisory Board was not given any information about the radionuclide composition of the radioactive waste and the longevity of the waste.

Public comment is being accepted for the disgraceful proposal to forever poison Idaho. See the document at https://idaho-environmental.com/Community/calcine and submit comments to DraftCCSSFBasisDocument@icp.doe.gov. Neither the Department of Energy's presentation to the Citizens Advisory Board nor its Public Involvement Opportunities webpage [3] identify the comment period dates, but say it is a 45-day comment period.

The ICP CAB meeting public outreach summary states that a meeting will be held in November for the public to ask questions, but does not say the date of the meeting or where to locate this information.

The 1995 Idaho Settlement Agreement [4] requires packaging of the calcine in order to ship it and requires shipping the calcine to an as of yet unidentified repository by 2035. The serious hazard posed by calcine waste storage is not discussed in any meaningful way but is instead waived away in LINE presentations and is not presented in IDEQ distributed literature concerning the calcine. The presumed low risk is not backed up by any meaningful disclosure of an adequate risk analysis. It is important to recognize the extraordinarily high quantity of calcine high-level waste that is essentially an enormous amount of spent nuclear fuel minus the contaminated uranium-235 that could only be used for a plutonium production reactor's fuel and volatiles already released to the Idaho skies. And the liquid rinse-out waste that was injected into the Snake River Plain aquifer to flow to the Magic Valley south of the INL and to the Snake River.

The hazard posed by the highly soluble and readily dispersible form of the calcine material must be respected. The **basic inability to mitigate a release from a calcine bin set must be recognized and emphasized** along with recognition of the inevitable far-reaching devastating **long-term environmental consequences that cannot be remediated** should a serious breach of one or calcine bin sets occur. Calcine blowing in the wind, with its powdered laundry detergent granularity, would be difficult or impossible to remediate. **Idaho must require the DOE to put the calcine into a less vulnerable condition and must do so with more urgency, not less, because of the lack of a designated repository for the high-level calcine waste.**

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[3] Department of Energy, DOE-ID, https://www.id.energy.gov/insideNEID/PublicInvolvement.htm

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

The DOE emphasizes that the bulk of the calcine radioactivity will decay away in a few hundred years; there are 33.1 million curies (assuming decay to 2016). The strontium-90 and cesium-137 do make up the bulk of the radioactivity, driving shielding needs and do pose a huge environmental hazard if released now. But often ignored in presentations to the public is the toxicity over millennia from other radioisotopes in the calcine, should they be allowed to migrate to the aquifer. If calcine were allowed to leach into soil from the vaults containing the bin sets, the calcine will leach into the aquifer. There would, realistically, be no cleaning up the contamination. Once in the aquifer, the contamination flows downstream to communities, even if the contamination lies deeper in the aquifer than is typically monitored or acknowledged.[5]

It is instructive to compare the quantities and radioisotopes of stored calcine to the waste buried at the Radioactive Waste Management Complex that will not be exhumed. [6] [7] Leaving aside the Sr-90 and Cs-137, the analysis of the buried waste migration at RWMC to the aquifer show that the dominant long-lived and mobile radioisotopes contributing the most to radiation dose come primarily from drinking water come from carbon-14, chlorine-36, iodine-129, technetium-99, neptunium-237, uranium, plutonium and americium-241.

The full inventory of calcine chemical and radionuclides are provided at the end of this letter in two tables from DOE/EIS-0287. [8] A comparison of radionuclide inventories for RWMC, the replacement for RWMC (the Remote-Handled Low-Level Waste Facility), [9] and calcine stored at INL are provided in Table 1 to highlight important radionuclides.

Table 2 provides some additional perspective on the large inventory of radioactive material in the calcine bin sets. It would require 1,975,000,000 billion liters of water (or over 800 Snake River Plain aquifers) to dilute the strontium-90/y-90 in calcine storage to federal drinking

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[5] Geophysical Logs and Water-Quality Data Collected for Boreholes Kimama-1A and -1B, and a Kimama Water Supply Well near Kimama, Southern Idaho By Brian V. Twining and Roy C. Bartholomay, 2011 Prepared in cooperation with the U.S. Department of Energy (DOE//ID 22215) Data Series 622. http://pubs.usgs.gov/ds/622/pdf/ds622.pdf Herein are presented deep aquifer contamination consistent with historical Idaho National Laboratory waste water releases, yet there is no stated recognition of that fact.

[6] U.S. Department of Energy, 2007. Performance Assessment for the RWMC Active Low-Level Waste Disposal Facility at the Idaho National Laboratory Site. DOE/NE-ID-11243. Idaho National Laboratory, Idaho Falls, ID and U.S. Department of Energy, 2008. Composite Analysis for the RWMC Active Low-Level Waste Disposal Facility at the Idaho National Laboratory Site. DOE/NE-ID-11244. Idaho National Laboratory, Idaho Falls, ID. (https://www.inl.gov/about-inl/general-information/research-library/ Search the DOE-ID Public Reading Room for the reports.

[7] See that the publicly available administrative record for RWMC cleanup does not contain the assessment of radionuclide migration and radioactive doses after 10,000 years. The pre-10,000 year contaminant migration is artificially suppressed for the first 10,000 years and then rapidly escalates and stays elevated for hundreds of thousands of years. See the Administrative Record at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) documents for documents associated with this cleanup action, including "Record of Decision" documents and EPA mandated Five-year Reviews at http://ar.inel.gov or http://ar.icp.doe.gov

[8] Idaho High-Level Waste and Facilities Disposition Final Environmental Impact Statement, DOE/EIS-0287, September 2002. http://energy.gov/nepa/downloads/eis-0287-final-environmental-impact-statement

[9] US Department of Energy, "Environmental Assessment for the Replacement Capability for Disposal of Remote-Handled Low-Level Radioactive Waste Generated at the Department of Energy's Idaho Site," Final, DOE/EA-1793, December 2011. http://energy.gov/sites/prod/files/EA-1793-FEA-2011.pdf

Table 1. Calcine bin set total radionuclide inventory comparison to the waste that will remain buried at RWMC and to the replacement for RWMC.

Radionuclide (half life)	**Calcine Inventory (curies)**	**Buried (existing) RWMC Inventory (curies)**	**Buried (future) Replacement RH-LLW Inventory (curies)**
Carbon-14 (5730 year)	0.038	731	432
Chlorine-36 (301,000 year)	0	1.66	260
Iodine-129 (17,000,000 year)	**1.6**	0.188	0.133
Technetium-99 (213,000 year)	**4600**	42.3	16.7
Neptunium-237 (2,144,000 year)	**470**	0.141	0.003
Uranium-232 (68.9 year)	1.6	10.6	0.00036
Uranium-233 (159,000 year) Product bred from U-235 and thorium, also decay of Np-237	0.057	2.12	0.0001
Uranium-234 (245,500 year) Pu-238 decay product	**130**	63.9	0.0012
Uranium-235 (703,800,000 year)	**3.2**	4.92	0.005
Uranium-236 (23,400,000 year) Pu-240 decay product	**11**	1.45	0.0001
Uranium-237 (0.0185 year to Np-237)	**1.5**	-	-
Uranium-238 (4,470,000,000 year)	3.1	148	16.2
Thorium-228 (1.92 year to radium-224)	1.6	10.5	-

Natural thorium decay and Pu-240 decay product			
Americium-241 (423 y decays to Np-237)	12,000	215,000	0.38
Plutonium-238 (87.7 year)	**110,000**	2080	-
Plutonum-239 (24,000 year)	**48,000**	64,100	-

Table notes: Calcine inventory from DOE/EIS-0287; RWMC buried waste inventory from DOE/NE-ID-11243/11244 (figures cited may not be the latest estimates); replacement remote-handled facility INL-EXT-11-23102.

Bold highlighting of calcine inventory indicates a similar or larger inventory than the buried RWMC waste. The RWMC buried waste is estimated by the DOE to yield 100 mrem/yr doses in drinking water for millennia unless a perfect soil cap limits the estimated doses to be 30 mrem/yr. Importantly, the inevitable spikes in contamination due to flooding have not been accounted for despite RWMC flooding in 1963 and 1969. The dose estimates are not conservative. The assumed dilution factors are not consistent with past INL aquifer contamination migration. Calcine migration Kd coefficients may be different than used for RWMC and may worsen the effect of calcine in the soil.

Table 2. Perspective on the quantity of radionuclides in the stored calcine.

Radionuclide (half life)	Inventory (curie)	Maximum Contaminant Level	Dilution volume (Liter) [b]	Number of Aquifers to Dilute
Sr-90/Y-90 (Sr-90 29.1 year)	15,800,000	8 pCi/L	1.975E+18 1,975,000,000 billion	809
Cs-137/Ba-137m (30.2 year)	17,300,000	160 pCi/L	1.081E+17 108,000,000 billion	44
C-14 (5,730 yr)	0.038	2000 pCi/L	1.90E+7 0.019 billion	<<1
Cl-36 (301,000 yr)	0	700 pCi/L	0	0
I-129 (17,000,000 yr)	1.6	1 pCi/L	1.6E+12 1600 billion	<<1
Tc-99 (2213,000 yr)	4600	900 pCi/L	5.11E+12 5110 billion	0.002
Np-237 (2,144,000 yr)	470	15 pCi/L[a]	3.13E+13 31,300 billion	0.0128
U-234 (245,500 yr)	130	15 pCi/L[a]	8.67E+12 8,670 billion	0.00355
Am-241	12,000	15 pCi/L[a]	8.0E+14	0.378

Radionuclide (half life)	Inventory (curie)	Maximum Contaminant Level	Dilution volume (Liter) [b]	Number of Aquifers to Dilute
(432 yr to Np-237)			800,000 billion	
Plutonium-238 (87.7 year)	110,000	15 pCi/L[a]	7.3E+15 7,300,000 billion	3
Plutonum-239 (24,000 year)	48,000	15 pCi/L[a]	3.2E15 3,200,000 billion	1.3

Table notes:

a. The unit of 1 picocurie/liter is 1.E-12 curie/liter. The limit is 15 pCi/L for total alpha (40 CFR 141). For uranium, total natural uranium limit of 30 microgram/liter for all combined uranium isotopes.

b. Aquifer volume of 2.44E+15 liters is assumed.

c. The dilution volume ignores soil adsorption and migration delay timing; it is provided to give some perspective on the amount of waste involved. It ignores that fact that the entire aquifer is not going to be involved with dilution, although waste in the aquifer can fan out and involve a considerable portion of the aquifer downstream.

water standards. It would require 7,300,000 billion liters of water (or over 3 Snake River Plain aquifers) to dilute the Pu-238 stored in the calcine to federal drinking water standards. It should also be pointed out that these figures are presented as though only a single contaminant were present. In reality, the health detriment of the combination of all contaminants in the drinking water must be considered. This is a point often overlooked by the Idaho Department of Environmental Quality as IDEQ surveys the contamination in the aquifer, dismissing any result below federal drinking water standards which have, for tritium and hexavalent chromium been found to not be protective of human health, especially when consumed over a lifetime. [10]

The graph of the migration of the buried waste at RWMC that will remain at RWMC buried in soil is shown below in Figure 1. The contamination migration is not realistically modeled by the DOE nor is it conservatively modeled. Flooding and fast paths of contaminant migration are ignored. [11] The ingestion doses will undoubtedly exceed the 30 to 100 mrem/yr radiation doses shown, intermittently at least.

Despite the overly optimistic statements made about the grouting below portions of the RWMC and untrue statements presented in LINE presentations about the short half-life of the material, the buried radioactive waste that is not being exhumed from the RWMC will continue to contaminate the Snake River Plain aquifer, essentially forever. EPA cleanup standards are discussed in relation to INL CERCLA cleanup but are rarely met and will not be met over the long term, after 10,000 years, beneath the RWMC.

[10] See www.environmental-defense-institute.org for discussion of more stringent tritium and hexavalent chromium regulations and public health goals that the current EPA federal drinking water standards.

[11] Johnson TM et al., *Geology*, "Groundwater "fast paths" in the Snake River Plain aquifer: Radiogenic isotope ratios as natural groundwater tracers," v. 28; no. 10; p. 871-874, October 2000.

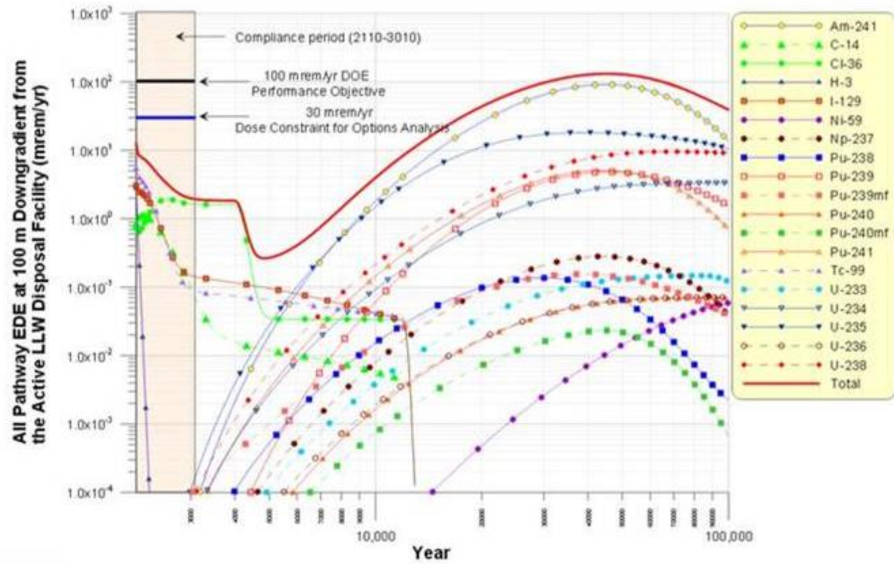


Figure 4-2. All-pathways effective dose equivalent 100 m downgradient from the Radioactive Waste Management Complex boundary from year 2110 to year 100,000 with cover infiltration rate equal to 1 cm/year.

Figure 1. All-pathways radiation dose for the Radioactive Waste Management Complex from DOE/NE-ID-11243 and DOE/NE-ID-11244. Americium-241, uranium-235, uranium-238, and plutonium-239 are top contributors to ingestion dose after 10,000 years. Beware, however, that contamination migration by the DOE appears to be modeled with a bias toward delaying the release timing to be after 10,000 years. The EPA ignores post-10,000 contamination in its INL CERLCA cleanup.

A revealing history of calcine storage seismic evaluation is presented in 2003 report INEEL/EXT-02-1548. [12] It is a "kick the can down the road" approach to seismic evaluation typical of high hazard INL nuclear facilities. There are seven bin sets, each designed and constructed differently; see figure at end of this letter from INEEL/EXT-02-1548. Each bin set for containing calcine is inside a concrete vault that is usually at least partially above ground. Initially, both the bin set and the vault were to be seismically evaluated for bin set 1.

Bin set 1, designed and built first, was found in 1989, upon visual inspection by EQE Engineering to be extremely seismically fragile. The INL then focuses on evaluation of the concrete vault which consultants conclude would "not collapse" in a severe seismic event. Yet unsaid is that structural failure of bin set 1 would be expected and the concrete vault would be cracked. Importantly, the calcine in bin set 1 would not be confined following a small seismic event.

[12] Department of Energy Idaho Operations Office, INEEL/EXT-02-01548, "Structural Integrity Program for the Calcined Solids Storage Facilities at the Idaho Nuclear Technology and Engineering Center," May 2003. Find it at https://inldigitallibrary.inl.gov

It is evident that as early as 1989, it was recognized that the importance of confining the calcine merited applying stringent seismic design criteria similar to a nuclear reactor, more stringent than the Performance Category 2 later adopted to argue that the calcine bin set 1 vault is satisfactory. Performance Category 2 seismic design criteria should never have been argued to be sufficient for the seismic performance requirement for INL calcine bin sets.

A 1994 report [13] explains that "Currently, Bin Set 1 is being evaluated to determine the seismic qualification of the bins and vault. Based on this study, retrieval of calcine from Bin Set 1 and transporting it to Bin Set 6 could be required." This was stated despite the inspection in 1989 that by visual inspection would have shown bin set 1 to be seismically fragile.

For the other calcine bin sets, the argument then shifts to more stringent seismic design criteria having been specified in safety analysis documents, but these safety analysis documents are unavailable to the public and cannot be reviewed as the basis for adequacy of the other calcine bin sets or vaults. At least it was recognized that the calcine storage facilities for bin sets 2 through 7 needed to meet seismic design criteria more stringent than PC-2. The fact that more stringent seismic design criteria were adopted for calcine storage facilities 2 through 7 is positive; **yet not all INL designed tank systems were actually adequately designed despite having adopted more stringent criteria**. Subsequent detailed design and installation should have been reviewed by qualified nuclear industry seismic structural engineering experts yet no evidence of seismic expert review of each bin set is evident except for bin set 1 which is obviously found to be seismically weak.

The Department of Energy did not take protecting Idaho seriously when it failed to provide safe storage of the calcine with regard to seismic events and flooding events. The Department of Energy never gave honest portrayal to the citizens and state officials of the hazards posed by the calcine. And now, a contrived charade to argue that permanent disposal of the calcine on the Idaho National Laboratory is acceptable is being made.

Given the extremely large inventory of hazardous material, the release of which cannot be remediated, it would be much more appropriate for the interests of protecting Idaho to require a higher level of seismic capability to withstand a more serious seismic event.

Idaho must require expedited repackaging of the calcine stored at the INL even if shipment of the calcine is not expected to occur in time to meet the 2035 shipment milestone stipulated in the Idaho Settlement Agreement.

The DOE's study ignores organ doses (see Section 7.1.1) and presumes that a 500 mrem dose to an embryo is acceptable despite diverse evidence that the unborn child would have higher risk of birth defects, cancer and leukemia at even 100 mrem doses.

[13] Department of Energy Idaho Operations Office, WINCO-1192, "ICPP Tank Farm System Analysis," January 1994. Find it at https://inldigitallibrary.inl.gov

Idaho Cleanup Project Integrated Waste Treatment Unit Treats Eight Percent of the Liquid Waste

While the radioactive liquid sodium-bearing waste was to have all been treated by the end of 2012, the redesign and testing of the facility continued for over a decade. This year, in 2023, the IWTU has now treated 8 percent of the liquid waste or 68,048 gallons. There are 772,766 gallons of radioactive waste remaining to be treated. So, it can be expected to take many more years to treat this sodium-bearing waste that is classified as high-level waste. There is no place to ship this waste to, after its treatment in the IWTU to put it in a dry form. [14]

Mercury is one of the toxic materials that escape in the gases and that they hope to capture with granular activated carbon beds. The IWTU burns coal powder and is polluting. It can also release radionuclides out the stack. No radiological monitoring of the IWTU effluent was presented. And no environmental monitoring quarterly results were available for the entire year. In the past, quarterly monitoring results would be provided throughout the year, while the final annual report would typically be published by June of the following year. The radiological monitoring reports, including the quarterly reports, are more and more tardy and unavailable. What are they hiding?

As a side point, none of the questions I have submitted to the Department of Energy's ICP CAB have been answered during the last two years. The first inquiry I made as to why, I was told that my handwriting on the small cards they provide were hard to read, so all my questions were simply tossed in the trash. I don't know their excuse for the most recent set of questions. Too hard to answer my questions?

Department of Energy Announces Idaho National Lab Land Use Opportunity

In October, the Department of Energy announced that it is considering leasing land on the 890-square-mile Idaho National Laboratory site to industry partners interested in developing carbon-free energy projects. Dr. Kathryn Huff, Assistant Secretary for the Office of Nuclear Energy and Dr. John Wagner, INL Director, discussed the possibilities at a meeting in Idaho Falls on October 25. [15] Community comments are due by 5 pm Mountain Time December 15, 2023 and decisions are not expected until later next year. [16] Carbon-free energy projects

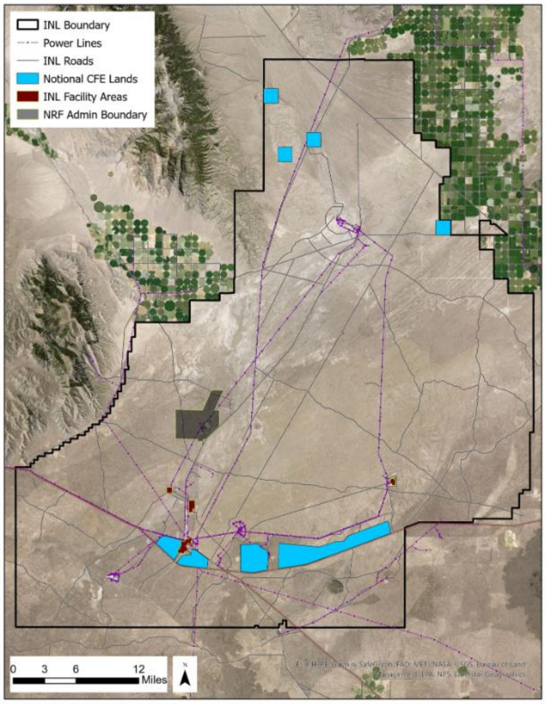
[14] Department of Energy, Idaho Cleanup Project Citizens Advisory Board for October 2023 at https://www.energy.gov/em/icpcab/articles/icp-cab-meeting-materials-october-2023 (See Idaho Cleanup Project Integrated Waste Treatment Unit presentation, October 25, 2023 and other presentations.)

[15] Stephanie Lucas, *KIFI Local News 8*, "Department of Energy announcement for Idaho National Lab land use," October 25, 2023.

[16] Department of Energy, Office of Nuclear Energy, U.S. Department of Energy Issues Request for Information on Potential Clean Energy Projects at Idaho National Laboratory, October 17, 2023. https://www.energy.gov/ne/articles/us-department-energy-issues-request-information-potential-clean-energy-projects-idaho and send comments to tanner.emrich@inl.gov (according to Request for Information RFI# INL-23-014)

including nuclear energy, wind, solar, geothermal, net-zero microgrids and other clean energy technologies are invited to participate. The cost of the lease is not being disclosed.

Potentially Available Lands for Lease



DOE has also issued Request for Information for the Hanford site in Washington, the Savannah River Site in South Carolina, the Nevada Security Site in Nevada, and the Waste Isolation Pilot Plant in New Mexico. The "Cleanup to Clean Energy" program is intended to help achieve President Biden's ambitious climate goals and the directive in Executive Order 14057 for agencies to use their properties to develop new clean electricity generation.

Areas at the Idaho National Laboratory to be considered for carbon-free leases are shown in the figure below. [17] These are all radiologically contaminated areas and receive continuing radiological airborne contamination. See EDI comments online. [18]

With ongoing tritium infested groundwater and air near the Idaho National Laboratory, let's look at tritium health risks

Tritium is a radioactive contaminant released by nuclear reactors and from nuclear weapons testing. Both the nuclear energy industry and the nuclear weapons industry have sought to minimize the perception of health harm from tritium. A new book by Arjun Makhijani, *Exploring Tritium's Dangers* [19] [20] provides important information regarding the harm of releasing man-made tritium into the environment.

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[17] Department of Energy, Contract Opportunity, Generating Carbon Pollution-Free Electricity on the Idaho National Site, Scoville, Idaho., Request for Information. https://sam.gov/opp/e22cfa2e47334524985608ff7ef9bb50/view and see file:///C:/Users/Thatcher/Downloads/2023.0.24.Industry+Day+RFI.pdf

[18] Tami Thatcher, Public Comment Submittal on Generating Carbon Pollution-Free Electricity on the Idaho National Laboratory Site, Scoville, Idaho, November 2, 2023. http://www.environmental-defense-institute.org/publications/EnergyCommentINL2023.pdf

[19] Robert Alvarez, Bulletin of the Atomic Scientists, "'Exploring Tritium's Danger': a book review," June 26, 2023. https://thebulletin.org/2023/06/exploring-tritiums-danger-a-book-review/

[20] Arjun Makhijani, Ph.D., *Exploring Tritium Dangers – Health and Ecosystem Risks of Internally Incorporated Radionuclides*, ISBN:978-1-62429-447-1. https://ieer.org/resource/books/exploring-tritim-dangers/ and file:///C:/Users/Thatcher/Downloads/Exploring-Tritum-Dangers.pdf

Nuclear promotors like to emphasize that radioactive tritium is produced naturally – but they don't like to admit how their industry pollutes air and water with much larger quantities than would occur naturally.

Nuclear weapons explosions beginning in 1945 had by 1963 caused rainfall in the Northern Hemisphere to be 1,000 times more tritium than natural background levels, along with other radionuclides. The radioactive half-life of tritium is 12.3 years. Although tritium is a weak beta emitter, tritium is spread throughout the body, and the U.S. nuclear industry greatly downplays the harm of tritium. Studies have shown that tritium's low energy beta are actually more efficient in producing deoxyribonucleic acid (DNA) double-strand breaks than cesium-137 gamma rays AND that the relative effectiveness of tritium is even greater for the production of complex double-strand breaks. [21]

Many people understand that the human body contains a lot of water. Water is made of hydrogen and oxygen. Tritium is a radioactive form of hydrogen and can be inhaled, ingested, or absorbed through the skin, spreading throughout the body.

Tritium, also called H-3, has a nucleus that contains one proton and two neutrons. Ordinary hydrogen contains one proton but no neutrons. Deuterium is a hydrogen form having one proton and one neutron. Deuterium is used in heavy-water reactors like the CANDU (Canada Deuterium Uranium) reactor design used in Canada.

Nuclear reactors produce tritium both as a fission product and as an activation product in the coolant water. The quantity of tritium produced in nuclear reactors is not uniform and depends on the type and size of the reactor. In pressurized light-water reactors, most of the tritium that is released to the environment is produced by the interaction of neutrons with boron and lithium. The boron is added to the primary coolant waste to control the rate of nuclear reactions in the fuel and the lithium is added to control corrosion. Tritium is also produced in the fuel of pressurized water and boiling water reactors from ternary fission or fission in which there are three fission fragments instead of just two fragments. Heavy water CANDU reactors use deuterium in the coolant. CANDU reactors are used in Canada, India and a few other countries, and they abundantly produce tritium. [22] Tritium is not held up in air or water filters.

It isn't easy to detect the low energy beta in tritium. Its average energy is 5.685 keV whereas cesium-137, for example, after beta decay into barium-137m, decays with an energy of 661.7 keV. Iodine-131 decays with an average gamma energy of 192 keV. The higher gamma energies are easier to detect and may then more often be recorded while the lower energy gammas may be

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[21] Ghassan Hamra, David Richardson, and Richard MacLehose, *Environmental Health Perspectives* and *International Society for Environmental Epidemiology (SEE)*, "Tritium: Relative Biological Effectiveness and Cancer Risk," webpage. https://ehp.niehs.nih.gov/doi/abs/10.1289/isee.2011.01549 See page 110 and 111.

[22] Arjun Makhijani, Ph.D., *Exploring Tritium Dangers – Health and Ecosystem Risks of Internally Incorporated Radionuclides*, ISBN:978-1-62429-447-1. https://ieer.org/resource/books/exploring-tritim-dangers/ and file:///C:/Users/Thatcher/Downloads/Exploring-Tritum-Dangers.pdf

undetected and unreported. This lack of reporting and the fact that tritium is only harmful once inside the body does not mean that tritium internal radiation is not harmful to human health.

Neither radiation thermo-luminescent badges nor Geiger counters detect tritium. The tritium in groundwater, surface water or rain can be measured by counting in a laboratory, sometimes for many hours or days. And the counting in a laboratory setting is affected by pollution in the region where the lab is located as well as radioactive releases in adjacent buildings. This has happened at the Idaho State University during its tritium counting. The public basically has to rely on the polluters to police themselves and this has meant the lack of adequate and timely reporting of radiological contamination.

Tritiated water (HTO) typically is thought to cause most of the dose, but other forms are organically bound tritium (OBT) and tritiated gas (HT). The OBT form may have longer retention times in the body, causing higher dose for the intake. **The Canadian Nuclear Safety Commission review of over 50 experimental studies found tritium to have a health risk 2.2 times higher than gamma radiation.** [23] In a study by Ghassan Hamra and others, the relative biological effectiveness of tritium intake was found to be 8 times higher than external gamma radiation for causing leukemia [including chronic lymphocytic leukemia (CLL)]. [24]

In mice experiments at high doses, tritium was found to cause tumors, cancer, and leukemia, including myeloid leukemia. Despite higher health harm than currently accepted modeling by the International Commission of Radiation Protection (ICRP) for the purpose of radiation protection, the ICRP continues to knowingly underestimate the harm of tritium.

The Department of Energy has long played down the significance of tritium releases to air and to groundwater. At the Idaho National Laboratory, by the 1960s, notoriously high levels of tritium were detected in groundwater from the injection of radioactive waste water from spent fuel reprocessing and from percolation ponds for Department of Energy nuclear reactors. [25]

The contaminated groundwater at the INL, with tritium that exceeded what is now the drinking water maximum contaminant level for tritium of 20,000 picocuries per liter, was then used for sprinkler irrigation of lawns, for drinking and for showering, particularly at aquifer downgradient Central Facilities Area. People were getting unmonitored tritium dose from breathing, having their morning coffee, water during the day, and after showering at the end of the work day, common especially for radiation workers and laborers. In most radiation worker

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[23] Canadian Nuclear Safety Commission, webpage, http://nuclearsafety.gc.ca/eng/resources/health/health-studies/tritium/health_effects_of_tritium.cfm with report, Health Effects, Dosimetry and Radiological Protection of Tritium INFO-0799, April 2010.

[24] Ghassan Hamra, David Richardson, and Richard MacLehose, *Environmental Health Perspectives* and *International Society for Environmental Epidemiology (SEE)*, "Tritium: Relative Biological Effectiveness and Cancer Risk," webpage. https://ehp.niehs.nih.gov/doi/abs/10.1289/isee.2011.01549

[25] Tami Thatcher, Environmental Defense Institute, "Tritium at 800 pCi/L in the Snake River Plain Aquifer in the Magic Valley at Kimama: Why This Matters," December 31, 2016 and updated January 2017. http://www.environmental-defense-institute.org/publications/kimamareport.pdf

studies, there is usually unmonitored and unknown tritium dose as well as unknown inhalation and ingestion of other radionuclides.

The Canadian study states that **the dose to the developing fetus was estimated as about double the dose received by the adult female via tritium intakes**. This is not taken into account in radiation worker limits for pregnant workers. Harm to the unborn from radiation was recognized nearly 20 years ago, where the required radiation exposure for a pregnant worker in Europe was reduced to 100 millirem but the limit remains at 500 millirem in the U.S. for a pregnant worker. In addition, neither limit for pregnant workers accounts for the higher relative biological effectiveness of tritium compared to gamma radiation. Harmful effects to the human fetus from ionizing radiation include mental retardation, delayed intrauterine growth, birth defects and childhood cancer.

While nuclear officialdom denies the seriousness of tritium intakes, evidence has been mounting that show tritium causes chromosome damage and damage to DNA. Many laboratory studies on animals have clearly demonstrated that tritium can induce cancer.

In mice, tritium in water, administered over several days, of about 100 rad, caused death by <u>hematopoietic syndrome</u>, not gastrointestinal syndrome. Hematopoietic syndrome means that death of blood cells and blood forming tissues in the bone marrow caused death.

In squirrel monkeys, large doses of tritium were noted to decrease the number of immature female germ cells, oocytes, in newborn progeny. Based on the study of mice, the female reproductive systems may be vulnerable to tritium exposure. Also, male mice suffered the reduction of spermatogonia from tritium.

The Canadian study reviewed radiation worker epidemiology, although most of it did not provide tritium monitoring and when tritium monitoring took place, the tritium dose was not disclosed. However, the study of 39,546 radiation workers in the United Kingdom between 146 to 1979 by Beral and others found that, overall, mortality rates among radiation workers were below the national mortality rates of England and Wales. This is often called the “healthy worker” effect because only healthy workers are hired and retained.

Of those workers, 1,416 workers were monitored for possible tritium exposure, and an increased rate of prostate cancer mortality was found. The highest mortality ratio, SMR=12.77, for prostate cancer was found in younger men who were monitored for possible tritium exposure and cumulative dose exceeded 5 rem from external and internal radiation. These men had 12.77 times the number of prostate cancer deaths compared to non-radiation workers.

In a follow-on study, prostate cancer mortality showed “a statistically significant associate with external exposure, largely confined to men who were also monitored for internal contamination by radionuclides other than plutonium.” Tritium and other internal radionuclide contamination increase the risk of death from prostate cancer, despite prostate cancer not being covered by the Energy Employee Occupational Illness Compensation Program Act in the U.S.

The tritium doses were not known and neither were the doses from other internal radionuclides. Death from prostate cancer might now be less likely due to better medical treatment. In any case, as typical of the Canadian report, the Canadian nuclear regulator goes on to conclude that positive association of tritium and disease are intermittent and inconsistent and therefore no inference can be made about the risk from tritium and "any connection between tritium exposure and these effects is tenuous at best."

The Canadian study also reviewed that another study found that **radiation workers monitored for tritium had excess mortality for testicular cancer**. As before, there was no specific tritium dose information available for the tritium-monitored workers and external radiation and other internal radionuclides were also present.

It should also be understood that tritium releases can cause polluting far and wide, of air, water and be incorporated into food. The more the general population is exposed, the comparison of the disease rates between the radiation worker population and the general population show less difference. Radiation worker epidemiology often focuses on death by the cancer rather than incidence and does not report the trend of the disease over time, as relates to the commencing of nuclear facility operations.

The federal drinking water standard for tritium is 20,000 picocuries per liter (pCi/L). [26] The State of California, however, studied the harm of tritium and concluded that the Public Health Goal should be that tritium in drinking water not exceed 400 pCi/L, based on known carcinogenic effects. [27] California's health goal for tritium in drinking water previously had been below 100 pCi/L, but California apparently raised the level without any new evidence. No one should actually consider 400 pCi/L tritium in drinking water to be benign because effects other than carcinogenic effects were not carefully studied and the effects of radiation on children and the unborn are several times higher than on adult men. Detrimental effects on the immune system from tritium, for example, are inadequately studied, but deaths occurring for reasons other than cancer are typically ignored.

NuScale investor woes and dismal outlook for UAMPS project

NuScale has subscribers for about 120 megawatts-electric (MWe) of power, but needs subscribers for an additional 250 MWe for the already scaled back project to continue. [28] The additional subscribers need to be found by early 2024 (February) or its initial subscribers at the Idaho UAMPS project can walk away from the project.

[26] U.S. Nuclear Regulatory Commission webpage, Backgrounder on Tritium, Radiation Protection Limits, and Drinking Water Standards, accessed November 1, 2023. https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/tritium-radiation-fs.html

[27] Office of Environmental Health Hazard Assessment California Environmental Protection Agency, *Public Health Goals for Chemicals in Drinking Water – Tritium*, March 2006. https://oehha.ca.gov/media/downloads/water/chemicals/phg/phgtritium030306.pdf

[28] Leonard Hyman & William Tilles, "American Small Reactor Development Suffers From Short Sellers," October 26, 2023. https://oilprice.com/Alternative-Energy/Nuclear-Power/American-Small-Reactor-Development-Suffers-From-Short-Sellers.html

Last January, the NuScale cost estimate increased to $89/megawatt-hour (MWh) from $58/MWh. [29] Without extremely generous government subsidies granted to NuScale, the cost would already approach $120/MWh. [30] Additional cost escalation and schedule slippage is realistic.

Originally, the project was for 12 modules but that was reduced to six 77 megawatt-electric (MWe) modules for a 462 MWe total capacity. Scaling down from 12 modules, the modified project slated at the Idaho National Laboratory is to deploy 6 reactor modules. The proposed power generation has been scaled up from 60 megawatt-electric (MWe) to 77 MWe each, and with all 6 modules operating could generator 462 MWe. The power level scale up for the NuScale US460 design has not been approved by the U.S. Nuclear Regulatory Commission.

Previously the NRC had reviewed the twelve 60 MWe module project, but had not guaranteed that the design was worthy of a construction permit. The U.S. NRC's communications to the Idaho Leadership in Nuclear Energy Commission at its October 2020 meeting[31] and to NuScale in writing regarding the original Standard Design Application for the 12-module 60 MWe reactors stated that **"… this [Nuclear Regulatory Commission] SDA [standard design approval] does not constitute a commitment to issue a permit, design certification (DC), or license…."** [32] [33]

Insiders have been selling off NuScale stock for over a year. Recently, NuScale has been impacted by a negative research report. The Rosen Law Firm announced that it is initiating an investigation of potential securities claims on behalf of shareholders. The firm is pursuing a class action recovery of shareholder losses. [34] Recent good news of future prospects of NuScale is seen as contrived and not credible by some experts.

NuScale makes inflated claims that the work they "have completed to date has advanced our nuclear power modules to the point that utilities, governments and industrials can rely on a

[29] David Schlissel, Institute for Energy Economics and Financial Analysis, "Eye-popping new cost estimates released for NuScale small modular reactor," January 11, 2023. https://ieefa.org/resources/eye-popping-new-cost-estimates-released-nuscale-small-modular-reactor

[30] David Schlissel, Institute for Energy Economics and Financial Analysis, "IEEFA U.S.: Small modular reactor 'too late, too expensive, too risky and too uncertain,'" February 2022. https://ieefa.org/articles/ieefa-us-small-modular-reactor-too-late-too-expensive-too-risky-and-too-uncertain

[31] Doug Hunter, CEO and General Manager of Utah Association of Municipal Power Systems (UAMPS), presentation to the Idaho Line Commission CFPP [Carbon Free Power Project] October 14, 2020. https://line.idaho.gov/wp-content/uploads/sites/84/2020/10/2020-1014-cfpp.pdf

[32] U.S. Nuclear Regulatory Commission, Letter from Anna H. Bradford, NRC to Zackary W. Rad, NuScale Power LLC, Subject: Final Safety Evaluation Report for the NuScale Standard Plant Design, August 28, 2020 at https://www.nrc.gov/docs/ML2023/ML20231A804.pdf

[33] U.S. Nuclear Regulatory Commission, Letter from Anna H. Bradford, NRC to Zackary W. Rad, NuScale Power LLC, Subject: Final Safety Evaluation Report for the NuScale Standard Plant Design, September 11, 2020 at https://www.nrc.gov/docs/ML2024/ML20247J564.pdf

[34] *Businesswire*, "ROSEN, SKILLED INVESTOR COUNSEL, Encourages NuScale Power Corporation Investors to Inquire About Securities Class Action Investigation – SMR," October 23, 2023. https://www.businesswire.com/news/home/20231023610651/en/ROSEN-SKILLED-INVESTOR-COUNSEL-Encourages-NuScale-Power-Corporation-Investors-to-Inquire-About-Securities-Class-Action-Investigation-%E2%80%93-SMR

proven SMR technology that has regulatory approval, is in active production and is ready for commercial deployment." [35]

The NuScale reactor module design has not been proven, and key equipment is novel and untested. While some components may be available, the NuScale promoters are greatly exaggerating the state of the NuScale design that has never been built or tested.

The novel steam generator design may be a cost and schedule buster and could, if it actually works, create safety problems as well as lead to premature permanent plant shutdown. There may be no practical way to repair the steam generator tubes, or it may simply be cost prohibitive.

A list of high impact technical issues yet to be resolved for NuScale's latest US460 Standard Design Approval application for the 6-pack reactor system is at https://www.nrc.gov/reactors/new-reactors/smr/licensing-activities/current-licensing-reviews/nuscale-us460.html Among various design changes, three of the issues pertain to the helical coil steam generators and the onset of density wave oscillations (DWO) induced loads.

The novel and untested helical steam generators pose a difficult challenge for the NuScale design. The unreliable performance of these proposed steam generators can cause reactor accidents that allow reactor coolant water to escape reactor containment.[36] The steam generator design is helical as opposed to the typical U-shaped or once-through steam generator tube design. The reliability of the helical steam generator tubes is unknown. The design of the helical coil steam generators is different from the design used in conventional pressurized water reactors because the primary coolant is flows on the outside of the tubes, or the shell side of the steam generator.

Failure of the helical steam generators, even without an accident, could force the premature closure of the project as these steam generators are integral to the reactor modules and may be extremely costly, if not impossible, to repair. [37] [38] Steam generator tube failure could be caused by a rapid propagation of a circumferential crack that leads to a double-ended rupture of the tube. [39]

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[35] *Businesswire*, "NuScale Power Comments on Inaccurate Short Seller Report," October 24, 2023. https://www.businesswire.com/news/home/20231024578361/en/nuscale-power-comments-on-inaccurate-short-seller-report and see also NuScale's website for its response.

[36] NuScale Final Safety Analysis Report, Probabilistic Risk Assessment, Docket No. 52-050, transmittal December 31, 2022 https://www.nrc.gov/docs/ML2236/ML22365A010.html

[37] Environmental Working Group, "Questions for NuScale VOYGR Reactor Certification: When Will It Be Done? And then, Will It Be Safe"," May 2023. Posted on the Institute for Energy and Environmental Research (IEER.org) website. https://ieer.org/resource/reports/questions-for-nuscale-voygr-reactor-certification-when-will-it-be-done-and-then-will-it-be-safe/

[38] Grant Smith and Anthony Lacey, EWG.org, "Small size, big problems: NuScale's troublesome small modular nuclear reactor plan," July 11, 2023. https://www.ewg.org/news-insights/news/2023/07/small-size-big-problems-nuscales-troublesome-small-modular-nuclear

[39] NuScale Final Safety Analysis Report, Chapter 15, Docket No. 52-050, transmittal December 31, 2022. https://www.nrc.gov/docs/ML2236/ML22365A006.html

Based on NuScale's probabilistic risk assessment, accident risk for the NuScale design, despite its natural circulation features, is still heavily influenced by loss of support systems and by operator error. These and other documents for NuScale's latest standard design approval application are at https://www.nrc.gov/docs/ML2233/ML22339A066.html although may be heavily redacted.

Also, the spent nuclear fuel from NuScale's reactors will become stranded fuel and will require untold decades of storage and will disproportionately require more space in a repository. for each megawatt produced. [40]

Articles by Tami Thatcher for November 2023.

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[40] Lindsay M. Krall, Allison M. Macfarlane, and Rodney C. Ewing, *PNAS*, "Nuclear waste from small modular reactors," Received June 26, 2021, Published May 31, 2022, https://doi.org/10.1073/pnas.2111833119.