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A review of the stated hematologic effect of radiation exposure to the Pacific Marshall Islanders from the 1954 Castle Bravo nuclear weapons test

An initial report of the impact of the March 1954 Bravo (Castle series) nuclear weapons test conducted by the U.S. would dismiss the alpha radiation fallout of plutonium, dismiss the internal radiation health hazard, and would state: "According to laboratory hematological data on these natives, the whole body gamma dose approached lethal levels, yet these natives who for the most part, remained in the open during active fall-out, received burns limited to unclothed parts of the body or in areas where perspiration carried contamination into clothed areas." [1]

It would seem that what they were implying was that the nuclear weapons testing had not been very harmful, despite reaching what they estimated were whole body gamma doses that approached lethal levels. The statement also implies that the blood changes detected following the nuclear test were used to estimate the external radiation dose, without consideration of the intake of plutonium and other actinides that would also cause blood changes.

The narrative was contrived in the report by Maxwell that alpha inhalation was not of concern and it was not of respirable particle size.

The U.S. Atomic Energy Commission would repeatedly say that the radioactive fallout from the 1954 Bravo test was an accident due to (1) an unpredicted shift in winds and (2) greater than expected nuclear weapon test yield. Both statements were lies. Interestingly, formal plans were laid out in advance of the March 1954 nuclear test to medically examine people exposed to the heavy fallout.

There were more lies. The lie would persist that the fallout from the March 1954 test was limited to a handful of islands (Rongelap, Ailingnae and Utirik). Another lie was that the radioactive fallout problem was due to the March 1954 Bravo test and not the dozens of other high yield Castle series tests in 1954 and many other high yield tests in 1956, 1957 and 1958. Actual radiation fallout survey information was withheld. There were 67 nuclear tests conducted in the Marshall Islands from 1946 to 1958.

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[1] Roy D. Maxwell et al., *Evaluation of Radioactive Fallout*, Armed Forces Special Weapons Project, Washington, DC, 1955. See www.osti.gov. (This report is cited in *Nuclear Bodies: The Global Hibakusha* by Robert A. Jacobs, Yale University Press, 2022.)

Peripheral blood tests of 64 people from Pacific Island Rongelap and 18 people from Ailingnae commenced within 3 days of the March 1954 Bravo nuclear weapons test. A comparison of the sharp drop in blood lymphocytes to that expected from an external gamma dose would indicate a large external gamma dose. Alpha intakes of plutonium would also affect blood changes but appear to have been ignored.

Urine testing was conducted that showed high levels of radionuclides including strontium and iodine and yet the narrative had been promoted that inhalation of radionuclides was negligible. No gamma spectrometry of urine or other bioassay and no gamma spectrometry by whole body counting would be conducted until three years had elapsed from the weapons test. By then, many gamma emitters such as iodine-131, cerium-144, zirconium/niobium-95 and others would have decayed away.

The March 1954 Bravo nuclear weapons test forced the evacuation of islanders living on the island of Rongelap to temporary housing hundreds of miles away.

The radiological surveys released publicly of the Marshall Islands one year after U.S. nuclear weapons testing ignored all plutonium and other alpha emitters released from the Castle Bomb test that had been conducted in March 1954. The survey focused on general gross beta and gross gamma levels without specifically identifying any of the radionuclides detected.

A 1960 writeup of medical examinations conducted by Brookhaven National Laboratory of the islanders would go into extensive detail of many medical examinations of the islanders. [2] It was the usual ploy by the U.S. agencies to make it appear that comprehensive and thoughtful actions were being taken. And yet, the narrative of the reports was always arranged and communicated to minimize the appearance of any radiation-induced health problems. It was as though the careful dental examinations excused the lack of thoroughness regarding ongoing skin lesions from beta burns.

The exposed islanders on Rongelap were compared to islanders not on Rongelap during the March 1954 test.

In 1957, the U.S. returned the islanders to Rongelap because "after careful evaluation of the radioactive contamination situation, Rongelap Island was considered safe for habitation." [3]

After the return to Rongelap in 1957, the radioactive body burdens of the islanders then dramatically increased because of the contaminated food on the island. Radionuclides in food would increase the detected body burden of cesium-137 by factors of up to 100 and of strontium-90 by a factor of up to 20.

With gamma spectrometry of the islander's bodies, the prominent gamma peak for radioactive zinc-65 was now found in the islanders' bodies, both in the exposed and unexposed

[2] Robert A. Conard, M.D., et al., *Medical Survey of Rongelap People Five and Six Years After Exposure to Fallout (With an Addendum on Vegetation)*, BNL 609 (T-179) September 1960.

[3] Robert A. Conard, M.D., et al., *Medical Survey of Rongelap People Five and Six Years After Exposure to Fallout (With an Addendum on Vegetation)*, BNL 609 (T-179) September 1960.

group. The radioactive zinc-65 from the fallout was found in humans and was coming from ingestion of fish, from bioaccumulation from plankton to fish. [4]

The detection of substantial levels of zinc-65 in the bodies of the islanders is described in the 1960 report and also in a 2010 report to estimate the internal radiation doses. [5] The 2010 report shows radioactivity levels of zinc-65 at levels above that of cesium-137 in the islander's bodies. Zinc-65 has a 244-day radioactive decay half-life. Cesium-137 has a 30-year half-life.

The 2010 report states that "we assumed that [zinc-65] was produced by neutron activation of weapons materials and of entrained sea water, admittedly in small amounts, and was, therefore, present in local and regional fallout. The [zinc-65] was then apparently absorbed by phytoplankton in ocean and lagoon areas close to each atoll."

Both the islanders exposed to the March 1954 Bravo (Castle series) test and those unexposed to that test, after being returned to Rongelap, were now consuming highly radioactively contaminated food. The Brookhaven researchers continued to compare the "exposed" and "unexposed" islanders peripheral blood results for years after the 1954 nuclear test.

The stated estimated dose to islanders at Rongelap was 175 roentgen from external gamma radiation from the March 1954 Bravo test. Peripheral blood changes have been related to external gamma exposure. The limit of exposure to the public that would be published a few years later would be 0.5 rem, similar to 0.5 roentgen for external exposure.

Radiation exposure would be expected to cause a rapid and sharp drop in blood lymphocytes **with recovery to normal levels within months**. The peripheral blood tests of exposed islanders showed a drop in blood lymphocytes by the third day after the March 1954 weapons test, of 55 percent and other a slight recovery after six months. **At 2 years, the lymphocyte levels were still low.** Brookhaven tries to say the islanders are inherently anemic and the cause is not due to radiation exposure.

Radiation exposure would be expected to cause blood platelet levels to fall, reaching a low point perhaps within 20 days of exposure **with recovery to normal levels within months.** The platelet levels fell to about 30 percent of the normal values by the fourth week after the March 1954 weapons test. But after one year, the levels were still below normal. **Brookhaven never investigates why the low blood lymphocyte and platelet levels fail to recover.**

Furthermore, Brookhaven compares the Rongelap exposed islanders to "unexposed" islanders who also have significant radiation exposure and significant radioactive food and water intakes.

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[4] Rinehart, R.W., et al., *Residual Contamination of Plants, Animals, Soil and Water of the Marshall Islands One Year Following Operation Castle Fallout*, USNRDL-454, 1955. www.osti.gov/opennet/servlets/purl/16383569.pdf

[5] Steven L. Simon, et al., Health Phys., Acute and Chronic Intakes of Fallout Radionuclides by Marshallese From Nuclear Weapons Testing at Bikini and Enewetak and Related Internal Radiation Doses, August 2010. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4049088/

Chronic radionuclide intakes from food ingestion were unmeasured, unmentioned and were occurring not only for the March 1954 Castle Bravo nuclear test but also from previous and later continuing nuclear weapons testing by the U.S. in the Marshall Islands.

With unmeasured and unknown intakes of plutonium and americium, and with unknown intakes of many red bone marrow seeking radionuclides such as strontium-90, cesium-137, iron-55, ruthenium-106, antimony-125 and cerium-144, these ingestion intakes could explain the slow, uneven failure of peripheral blood count recovery. And there were ongoing nuclear tests being conducted in the Marshall Islands.

The U.S. research reports listed above tend to understate to harm and to not investigate the incongruencies. The rapid drop in blood lymphocytes was noted in 1960 but unexplained. The absolute lymphocyte counts decreased again in 1960, with the mean dropping from 4000 in 1959 to 2700 in 1960. [6] There were no nuclear weapons tests on the islands in 1959 or 1960, but there had been heavy testing in mid-1958. The timing and the detail of the environmental monitoring and monitoring of body burden and urine excretion were not precise enough to determine the cause.

A 1980 report emphasized "The general health of the exposed Marshallese people (except for abnormalities associated with thyroid injury) has remained good and about the same as that observed in the unexposed populations examined. Vital statistics suggest that mortality and fertility rates have been about the same in the exposed as in the unexposed people. During the first four year there appeared to be an increase in the incidence of miscarriage and stillbirths in the exposed Rongelap women, but this observation was uncertain in view of the small numbers involved. Genetic studies and examinations of the newborn did not reveal any detectable abnormalities in the children of exposed parents that might have been related to radiation exposure. Probably related to radiation exposure was the finding of a slight increase in chromosomal aberrations in the lymphocytes of some Rongelap people at 10 years after exposure." Also, "In 1972 a Rongelap male, exposed at one year of age, died of acute myelogenous leukemia, and another Rongelap male died from carcinoma of the stomach." "The most widespread late effect of fallout exposure in the Marshallese has been the development of thyroid abnormalities – benign and malignant neoplasms and hypofunction of the gland. These as well as growth retardation associated with thyroid injury in some of the children, have been discussed in detail in this report." [7]

For more information about the health effects and after math from the U.S. bomb tests over the Pacific islands and the repeated deceptions about the consequences, read Giff Johnson, *Don't Ever Whisper —Darlene Keju, Pacific Health Pioneer, Champion for Nuclear Survivors*. [8]

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[6] Robert A. Conard, M.D., et al., *Medical Survey of Rongelap People Five and Six Years After Exposure to Fallout (With an Addendum on Vegetation)*, BNL 609 (T-179) September 1960. See page 35.

[7] Robert A. Conard, M.D., et al., Brookhaven National Laboratory, *Review of Medical Findings in a Marshallese Population Twenty-Six Years After Accidental Exposure to Radioactive Fallout*, BNL 51261, January 1980.

[8] Giff Johnson, *Don't Ever Whisper – Pacific Health Pioneer, Darlene Keju, Champion for Nuclear Survivors*, 2013. ISBN-10: 1489509062.

Darlene Keju, a Marshall Islander, died at age 45 after several years of battling cancer. She was not among those included in the group considered highly exposed to the 1954 Bravo nuclear test.

Also, read the new book by Robert A. Jacobs, *Nuclear Bodies: The Global Hibakusha*.

As I review the U.S. funded reports I have cited in this article, I can see more clearly that these U.S. researchers were active participants in covering up the harm the U.S. had knowingly inflicted on the Marshall Islanders. They actively withheld information about radiation surveys, the radioactivity of food on the islands, and the radioactivity in the Islander's bodies.

Here in Idaho, the Atomic Energy Commission was pummeling the people of southeast Idaho with radioactive fallout from the Idaho National Laboratory and from the Nevada Test Site. The radiological releases from the Idaho National Laboratory from 1952 to 1989 are described in the historical dose evaluation for the Idaho National Engineering Laboratory, the INEL HDE, although it underestimates the releases and deliberately omits key radionuclides such as plutonium-241 and americium-241. [9]

The radiation monitoring conducted by the Atomic Energy Commission in the Marshall Islands and here in southeast Idaho was designed to not reveal the truth of what was going on. People would not like the sound of being showered with plutonium that never decays away and so it was not mentioned. Boxes of monitoring records were destroyed prior to publishing the INEL HDE.

The health effects of people living in the radioactive fallout of the Department Energy's Idaho National Laboratory and the adverse health effects of the Marshallese have many similarities. And it is no wonder why documents about the health harm to the Marshall Islanders was included in the Human Radiation Experiments collection relevant to southeast Idaho. My great-grandmother exposed to Idaho National Laboratory fallout in the 1950s died of acute myelogenous leukemia, my grandmother died of thyroid-related cancer, and the number of thyroid cancers in southeast Idaho is double that of the rest of the state and the U.S.

New Book About the Wide-Reaching Harm of Nuclear Weapons and Nuclear Waste by Robert A. Jacobs

The recent book *Nuclear Bodies: The Global Hibakusha* by Robert A. Jacobs is a thoughtful look at the destruction of cultures as well as the destruction of bodies and the environment by the nuclear weapons and nuclear energy industries. [10]

Jacobs is a professor at the Hiroshima Peace Institute of Hiroshima City University. He has lived in Hiroshima and was in Japan during the 2011 Fukushima nuclear disaster.

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[9] 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

[10] Robert A. Jacobs, *Nuclear Bodies: The Global Hibakusha*, Yale University Press, 2022.

He explains the impact of the cold war, a limited nuclear war that has been inflicted on the environment and human bodies. From nuclear weapons testing to nuclear power plant disasters at Chernobyl and Fukushima, this comprehensive account of the contamination of land and human bodies "necessitates a profound rethinking of the meaning, costs and legacies of our embrace of nuclear weapons and technologies."

In thoughtful and readable prose, he explains the deceptions and the cost of continuing misplaced faith in the ability to isolate, successfully, spent nuclear fuel from the biosphere.

For anyone willing to understand the truth about the past nuclear weapons use and testing, about past nuclear accidents and about the future of nuclear waste, this book is highly recommended. Find it, buy it and read it! And don't fall into the trap of believing the nuclear promoter's claims of competency for protecting life on this planet for millennia from the toxic nuclear waste they are creating.

Idaho Department of Water Resources sets its sites on ignoring any flooding beyond 1-in-100-year levels as Montana's recent flooding exceeds 1-in-500-year flood levels

The recent rulemaking effort by the Idaho Department of Water Resources has sought to not concern itself with design criteria for floods larger than 1-in-100-year floods, June has brought heavy rain on top of snow pack in Montana, and heavy flooding.

According to the Associated Press, the equivalent of nine inches of rain flowed down Montana mountain slopes in some places. Half of more was from the melting snow, scientists said." [11]

According to hydrologist Tom Osborne, "One gage on the Stillwater River near Absarokee… normally flows at 7,000 cubic feet per second during a moderate flood and races as 12,400 cubic feet per second in a 100-year flood…" A once-in-500-year flood would mean water raging at 14,400 cubic feet per second. Preliminary numbers show that on Monday [June 13, 2022] it crested at 23,700 cubic feet per second.

If you had thought that drought meant less flood hazard, think again. The dry winter had little snow pack until a late spring heavy snow in the mountains of Montana that was followed by heavy rain and warm temperatures.

This can happen in Idaho and this sort of flooding has the potential to affect the safety of dams, the safety of dams that may hold mine tailings and the safety of mine tailing impoundment structures. The Mackay dam is a large size and high hazard dam that can cause flooding at the Idaho National Laboratory and may cause a radiological release from high-level waste called

[11] Associated Press, *The Idaho Falls Post Register*, "High and Fast – How heavy snow, rain flooded Yellowstone," June 19, 2022.

calcine as well as various storage systems of spent nuclear fuel at the Idaho Nuclear Technology and Engineering Center as well as pose a reactor safety challenge at the Advanced Test Reactor.

The recent rulemaking effort by the IDWR received negative comments and now we wait to see the IDWR's response. [12] See more in last month's June newsletter article: "Idaho Department of Water Resources changing the 'dam rules': Reducing requirements for new dams and actually eliminating dam release capacity safety requirements for existing dams (and mine tailings impoundment structures)."

My comments on the rulemaking were endorsed by the Idaho Conservation League. See all comments on the recent "dam safety" rulemaking effort at https://idwr.idaho.gov/legal-actions/rules/idwr-rulemaking-2022-2023/mine-tailings-impoundment-structures-safety-of-dams-rules/ .

Department of Energy continues to avoid discussing ongoing safety problems related to transuranic waste handling at the Idaho Cleanup Project

I had expected the June Idaho Cleanup Project Citizens Advisory Board meeting to have included discussion of recent transuranic waste problems, but the meeting was abruptly cancelled without notice to participants.

The Idaho Environmental Coalition (IEC) took over the Department of Energy's cleanup contract in January 2022. One of IEC's facilities is the Advanced Mixed Waste Treatment Project (AMWTP) that prepares transuranic waste for shipment to the Waste Isolation Pilot Plant (WIPP). The AMWTP had problems that led to a Stand Down in March. [13] [14] The details of the problems are startling.

In January and February of this year, Idaho Environmental Coalition was, for no particular reason, simply not performing numerous required safety requirements for treating transuranic waste containing high levels of uranium metal in RF-762 Pyrophoric Sludge that were specified in their RCRA permit.

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[12] Idaho Department of Water Resources rulemaking information page for IDAPA 37.03.05 (Mine Tailings Impoundment Structures) and 37.03.06 (Safety of Dams) is at https://idwr.idaho.gov/legal-actions/rules/idwr-rulemaking-2022-2023/mine-tailings-impoundment-structures-safety-of-dams-rules/ and general web address www.idwr.idaho.gov There is an Idaho Executive Order 2020-01, called Zero-Based Regulation that calls for Idaho agencies such as the Idaho Department of Water Resources to, for no other reason, to gut their laws and start anew. This negotiated rulemaking is authorized pursuant to Section(s) 42-1710 and 42-1714, Idaho Code. Public comment was sought prior to the formal rule making; however, almost no one of the public heard about it.

[13] Department of Energy Occurrence Report, "Less Than Adequate Conduct of Operations for Multiple Procedure Violations," Advanced Mixed Waste Treatment Facility, EM-ID—IEC-AMWTF-2022-0001. Notification date: February 24, 2022.

[14] Defense Nuclear Facilities Safety Board memo from Erin A. McCullough to Christopher J. Roscetti, Subject: Idaho National Laboratory (INL) Report for March 2022, April 1, 2022. See dnfsb.org.

The Resource Conservation and Recovery Act (RCRA) hazardous waste permit with the State of Idaho required special fire protection configurations, a special "drop test" to check for pyrophoric reaction, and for thermal monitoring of the waste packaged in drums. These permit requirements were on numerous occasions, not being performed.

On March 30, 2022, the U.S. Environmental Protection Agency (EPA) Region 10 office issued a Notice of Deficiency to the Idaho Environmental Coalition Advanced Mixed Waste Treatment Facility and the Department of Energy Idaho Office. The specific violations concern failure to implement two engineering controls. One was for failing to monitor for potential post-packaging thermal reactions and the other was for not implementing special fire protection system configurations.

Note that this is the type of material that caused the four drums to heat up and overpressurize, ejecting their lids and expelling radioactive waste in a fabric enclosure in 2018. [15]

Then, on April 9, the Waste Isolation Pilot Plant (WIPP) in New Mexico discovered liquid in the TRUPACT-II shipping container holding the waste drums and this required an evacuation at WIPP. [16] [17] The radioactive liquid is prohibited in the transuranic waste accepted by WIPP and it required an evacuation because chemicals like polychlorinated biphenyls (PCBs) as well as radionuclides can be harmful, yet difficult to detect.

TRUPACT-II containers are used to ship contact-handled drums of transuranic waste to WIPP and usually hold six waste drums. The problem transuranic waste came from the Idaho National Laboratory and shipments from the INL were paused.

The TRUPACT-II holding the drums was shipped back to the Idaho National Laboratory where the drums and their contents were to be inspected in June.

The return of a waste shipment from WIPP back to Idaho is an unprecedented event.

The drums had been certified as not containing liquid prior to being shipped to WIPP. A drum could leak. But it should also be understood that the drums holding transuranic waste have vents to allow gases to escape and prevent overpressurizing the drum under normal, expected conditions.

Sludge wastes in transuranic waste can appear dry, but are also known to hold liquids, which can separate from the sludge material during freeze-thaw cycles. Liquid in waste drums that has

[15] Idaho Cleanup Project Core, "Formal Cause Analysis for the ARP V (WFM-1617) Drum Event at the RWMC," October 2018. https://fluor-idaho.com/Portals/0/Documents/04_%20Community/8283498_RPT-1659.pdf

[16] Defense Nuclear Facilities Safety Board memo from Alexander Velazquez-Lozada to Christopher J. Roscetti, Subject: Waste Isolation Pilot Plant (WIPP) Report for April 2022, May 6, 2022. See dnfsb.org.

[17] Maire O'Neill, *Los Alamos Reporter*, "Discovery of Radioactive Liquid in TRUPACT-II Container At WIPP Causes Evacuation of Contact-Handled Waste Bay," April 11, 2022. https://losalamosreporter.com/2022/04/11/discovery-of-radioactive-liquid-in-trupact-ii-container-at-wipp-causes-evacuation-of-contact-handling-bay/

separated from the sludge matrix is treated by adding a liquid absorbent before shipping the waste to WIPP.

The non-conforming waste came from the AMWTP facility, but the waste stream of the problem waste have not been disclosed. In fact, as of May 31, the Department of Energy and its cleanup contractor, the Idaho Environmental Coalition, have been completely silent about the April 9 liquid discovery in a TRUPACT-II from Idaho at WIPP.

The Idaho Department of Environmental Quality has communicated in a letter that pinhole leaks were found in one of the drums, and that the drums in the TRUPACT-II returned to Idaho had come from the AMWTP. The pin hole leak problem was a condition that has been observed with older drums at the Advanced Mixed Waste Treatment Project. [18]

However, the presence of pin holes does not explain why liquid was present. Liquid, which is a prohibited material in the waste sent to WIPP, is to have been addressed by mixing in an absorbent material. The shipping of prohibited liquid to WIPP shows a failure to meet WIPP waste acceptance criteria which would not be limited to AMWTP but would also apply to the transuranic waste processes at the Radioactive Waste Management Complex (RWMC).

Despite the tendency of IEC to ignore its RCRA permit for handling transuranic waste, the Idaho Department of Environmental Quality appears to be satisfied by IEC excuses and it appears poised to rubberstamp the Department of Energy's RWMC Accelerated Retrieval Project RCRA permit for IEC's handling of transuranic waste. [19]

The EPA violations and the unprecedented return of waste from WIPP back to Idaho is newsworthy. Too bad it just isn't in the news.

Study Finds That Small Modular Reactors Worsen Spent Nuclear Fuel Disposal Issues

The promotors of small modular reactors (SMRs) have long claimed that their reactors will reduce spent nuclear fuel waste burdens. The impact that these various small modular reactor fuel cycles will have on nuclear waste management and disposal has been generally neglected. A recent study referred to as the Stanford study evaluated several small modular reactor designs

[18] State of Idaho Department of Environmental Quality, Letter from Daryl Sawyer to Tami Thatcher, Subject: Request for Extension of Public Comment Period for Renewal of the Partial Permit for the Radioactive Waste Management Complex Accelerated Retrieval Project (RWMC ARP) at the Idaho National Laboratory, EPA ID# ID4890008952, June 23, 2022.

[19] Notice of Intent to Renew Partial Permit for Hazardous Waste Storage and Treatment at the Idaho National Laboratory. A public comment period begins May 6 and ends on June 20, 2022 for the Draft Hazardous Waste Management Act/Resource Conservation and Recovery Act Storage and Treatment Partial Permit Renewal for the Radioactive Waste Management Complex Accelerated Retrieval Project on the Idaho National Laboratory, EPA ID# ID4890008952. See the permit at https://www.deq.idaho.gov/public-information/public-comment-opportunities Current permits are also at the deq.idaho.gov website.

and found that the claims that SMRs would reduce spent nuclear fuel waste burdens were untrue.[20] [21]

Small modular reactors are typically less than 300 megawatt per module. There are a wide variety of small modular reactors being proposed, including NuScale (a pressurized water reactor type), TerraPower (a sodium-cooled reactor type), Terrestrial Energy (a molten salt reactor type) and others.

The study found that compared with existing full-sized pressurized water reactors (PWRs), that small modular reactors will increase the volume, cost and complexity of spent fuel and radioactive waste disposal.

The spent nuclear fuel from small modular reactors will not reduce the generation of geochemically mobile iodine-129, technetium-99 and selenium-79, which are important dose contributors for spent nuclear fuel repository designs.

But more importantly, the high fissile nuclide concentrations and high decay heat loads will require more space in a repository.

The relatively high concentrations of fissile nuclides (uranium-235, plutonium-239 and plutonium-241) remaining in the spent fuel will require novel approaches to evaluating criticality during storage and disposal. The currently submitted NRC-license application for NuScale would indicate a low burnup such that its spent fuel will not meet existing repository criticality guidelines. But NuScale has many pending changes to the plans it has submitted to the NRC.

Sodium-cooled small modular reactor designs will generate spent fuel with high fissile isotope concentrations. This will mean less fuel allowed per disposal canister, greatly increasing the volume of storage needed in a repository.

Sodium-cooled fast reactors will produce fuel with higher decay heat. And this will require additional repository space to limit the heating of the repository. In addition, the sodium- or molten-salt-based coolants with their tendency to generate explosive or corrosive by-products upon contact with air or moisture will complicate their storage, decontamination and disposal.

The mess created by molten salt reactors decades ago Oak Ridge have yet to be cleaned up and the Department of Energy plans to entomb the molten salt reactor at Oak Ridge on-site. There was limited information available about various proposed molten salt reactor designs.

In addition to the spent nuclear fuel, the low- and intermediate-level waste (LILW) generated by SMRs will be greater than for energy-equivalent light-water reactors. The steel vessels and piping may have sufficient activities of long-lived nickel-59, nickel-63, carbon-14, niobium-94 and molybdenum-93 to warrant geologic disposal of the activated metal components.

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[20] Lindsay M. Krall, Allison M. Macfarlane and Rodney C. Ewing, *Environmental Sciences*, "Nuclear waste from small modular reactors," May 31, 2022. https://doi.org/10.1073/pnas.2111833119 and https://www.pnas.org/doi/10.1073/pnas.2111833119

[21] Jeff Robinson, *The Idaho Falls Post Register*, "Study casts doubt on SMRs clean-energy claims," June 5, 2022.

The NuScale founder Dr. Jose Reyes claimed that the study had factual errors related to NuScales design because it used outdated information and the wrong fuel burnup. The study used available information that has been submitted to the U.S. Nuclear Regulatory Commission but Reyes thought that the study should have used information that has not yet been submitted to the NRC but that he plans to submit to the NRC.

Another critic of the study, David LeBlanc, claimed that "no reactor uses or proposes using pyrophoric fuels." Actually, uranium and plutonium metals are pyrophoric as is zirconium-cladding. And he objected to statements that the chemically reactive sodium coolant would become *highly* radioactive after use. It was also suggested that the study of disposal options is an improper exercise based on the fact that these reactors are not yet operating. See the smoke-filled but fact-light arguments made against the Stanford study in a June 12 article by The Idaho Falls Post Register. [22]

I suggest that people read the Stanford study for themselves. It is obvious and I have written about it before that each new type of reactor creates additional complexity and expense for spent nuclear fuel disposal (see February 2021 and March 2022 Environmental Defense Institute newsletters.) The degree to which the small modular reactors pose added complexity and costs for spent fuel disposal is something that the Department of Energy is ignoring, something that the U.S. Nuclear Regulatory Commission is ignoring and it is something that the taxpayer's and electricity rate payers will be paying for, dearly, in the future.

Articles by Tami Thatcher for July 2022.

[22] Jeff Robinson, *The Idaho Falls Post Register*, "Nuclear experts, small modular reactor makers take issue with Stanford study," June 12, 2022.