The following article is taken from Environmental Defense Institute, News on Environmental Health and Safety Issues, January 2021, Volume 32, Number 1, written by **Tami Thatcher.**

Environmenal Defense Institute: http://www.environmental-defense-institute.org/

The NRC Required Canistered Spent Nuclear Fuel To Be Retrievable– But It Isn't and Prevalent Canister Storage Poses Huge Safety Risks as Well as Higher Disposal Costs

The elephant in the room regarding the safety and disposal of the growing number of welded-closed spent nuclear fuel canisters prevalently used by U.S. commercial nuclear power utilities is rarely discussed.

While cutting open these spent nuclear fuel dry storage canisters may be possible, in twenty years of talking about it, the method to use for cutting open the canisters has not been decided. No design has progressed beyond a vague conceptual stage. Nor have the risks been presented.

The U.S. Department of Energy's proposed Yucca Mountain spent fuel and high-level waste repository discussed dry transfer and wet transfer systems for years, and wildly vacillated about the size of spent fuel pools and capability of dry transfer systems, especially in regard to how to repackage commercial spent nuclear fuel received in non-disposal canisters.[1][2]

In one study performed for the Department of Energy in 2000, two options for cutting open the non-disposable spent nuclear fuel canisters were discussed. [3] But neither option included any specific method for the proposed remote cutting operation and the radiological accident risks were not evaluated. The study did acknowledge that determining the specific methods for cutting open the canisters would be a significant task. The range of safety issues associated with cutting open canisters containing high burnup fuel now used by utilities was not developed.

In a study for the Department of Energy published in 2015, eight proposed methods for cutting open non-disposable canisters were evaluated, [4] indicating that no method has actually been fully designed or used.

And what about the dry transfer system designed for the Idaho National Laboratory that remains to be built? The environmental impact statement (EIS) for the proposed Idaho Spent

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[1]P. W. McDaniel et al., Prepared for U.S. Department of Energy by Bechtel SAIC, *Yucca Mountain Project Surface Facilities Design*, November 2002. https://www.osti.gov/servlets/purl/808023

[2]Senate Hearing 109-523, Yucca Mountain Repository Project, May 16, 2006. https://www.govinfo.gov/content/pkg/CHRG-109shrg29473/html/CHRG-109shrg29473.htm

[3]Prepared for U.S. Department of Energy by TRW Environmental Safety Systems Inc., Civilian Radioactive Waste Management System Management & Operating Contractor, *White Paper: Waste Handling Building Conceptual Study*, TDR-WHS-SE-000002 Rev 00, October 2000. https://www.osti.gov/servlets/purl/893534-wmX91n/

[4]Sven Bader et al., *A study of transfer of UNF [used nuclear fuel] from non-disposable canisters – 15388, WM Symposia, Inc.*, July 2015. **https://www.osti.gov/biblio/22824303**

Nuclear Fuel Facility addressed the need to repackage only very specific Department of Energy spent nuclear fuel: high-temperature gas-cooled Peach Bottom reactor fuel, light-water breeder reactor Shippingport fuel, and research TRIGA fuel.[5] The easy-breezy EIS assumes away fuel drop events and essentially all accidents. [6]These fuels are less susceptible to oxidation than typical uranium oxide fuels used by the commercial nuclear power generating industry in the U.S. There are no operations involving large welded closed commercial spent nuclear fuel canisters at the proposed Idaho Spent Fuel Facility designed by Foster Wheeler Environmental Corporation.

In 2010, the U.S. Nuclear Waste Technical Review Board (NWTRB) recommended the "design and demonstration of dry-transfer fuel systems for removing fuel from casks and canisters following extended dry storage." [7] But this still hasn't happened.

In addition to the costs associated with spent nuclear fuel disposal because the industry's welded canisters were not considered suitable for disposal, the U.S. Nuclear Regulatory Commission has not grappled with the safety ramifications of not being able to retrieve spent fuel from these canisters, should one be damaged.[8]

In a dangerous and exceedingly dishonest way, the NRC has stipulated that aging degradation will not be included in its risk assessment of the canisters, despite known high likelihood, ineffective inspection programs and essentially no means for addressing aging degradation of the dry storage canisters predominantly used by the commercial nuclear industry.

The stainless steel that the canisters are made of has long been known to be vulnerable to aging failures such as chloride-induced stress corrosion cracking. The NRC has even recognized that such events are to be expected and yet continues to officially deemed the events "incredible." What are the potential radiological consequences of spent fuel canister breaches? I'll discuss that in the next article.

To underscore the extent of the U.S. Nuclear Regulatory Commission's lack of concern for the cost or even feasibility of its assumptions regarding consolidated interim storage, it is interesting to review the license the NRC granted for the proposed facility in Utah, the Private Fuel Storage facility.

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[5] Training, Research, and Isotope reactor fuel by General Atomics (TRIGA) fuel was used in various reactors built by General Atomics and is high enriched fuel. Many of the 1600 TRIGA fuel elements are stored at the Idaho National Laboratory in 2004 when the EIS was written but additional shipping to the INL was also needed.

[6]U.S. Nuclear Regulatory Commission, *Environmental Impact Statement for the Proposed Idaho Spent Fuel Facility at the Idaho National Engineering and Environmental Laboratory in Butte County, Idaho,* NUREG-1773, 2004. https://www.nrc.gov/docs/ML0404/ML040490135.pdf design by Foster Wheeler Environmental Corporation.

[7] U.S. Nuclear Waste Technical Review Board, *Evaluation of the Technical Basis for Extended Dry Storage and Transportation of Used Nuclear Fuel*. Arlington, Virginia, 2010. pp. 14 and 125, (at www.nwtrb.gov) as cited in https://info.ornl.gov/sites/publications/files/Pub60236.pdf

[8]Read the Environmental Defense Institute December 2020 newsletter, including "Devil in the details of the Standard Contract with the Department of Energy under the NWPA" and "The 'Nuclear Waste Fund' fee is no longer being collected from commercial nuclear power utilities – because the Department of Energy has no spent fuel disposal program," at http://www.environmental-defense-institute.org/publications/News.20.Dec.pdf

The U.S. Nuclear Regulatory Commission granted a license for interim storage of spent nuclear fuel in Utah, in 2005, to Private Fuel Storage (PFS), on the Goshute Indian Reservation. The facility was fought by the State of Utah and not built. The concerns by the State of Utah included the problem that the Department of Energy in October 2005 had announced a strategy to accept disposal canisters rather than the dual purpose (storage and transportation) canisters to be used at PFS. [9]The proposed interim storage facility at Utah would not have capability to repackage the canisters to a type approved of by the Department of Energy.

The NRC Licensing Board said that the issue was of no concern for the NRC. **If the canisters required repackaging, then the canisters shipped to PFS in Utah would have to be shipped back to the utilities, at the utilities expense, to repackage the canisters.** To the NRC, the issue did not affect the PFS licensing approval or the environmental impact statement for PFS. [10]

The NRC decided that it was not the NRC's problem if there was no place to ship the canisters to and no financial resources to ship or repackage the canisters. And the NRC didn't care if it actually was not possible to safely retrieve the spent fuel from the non-disposable canisters and place the spent fuel into different canisters.

The license was granted to PFS by the NRC only by the NRC refusing to care about the costs, risks and lack of capability to actually repackage the canisters. The NRC just said the problem didn't exist because the canisters at PFS would be shipped back to the utilities. Those utilities could include stranded fuel sites with no capability to repackage the canisters. This is how short-sighted, immoral and outrageous the U.S. NRC is. And the same thing is happening as the NRC prepares to approve consolidated interim storage in New Mexico and Texas.

Ironically, the entire stated reason for the consolidated interim storage proposed at New Mexico and Texas is to repurpose the land where the spent nuclear fuel is currently stored — and this is where the canisters would be sent back to for repackaging or if the license at the interim storage facility was not extended.

Spent Nuclear Fuel Canister Breaches — The Potential Radiological Releases are Too Scary for the NRC to Admit

The U.S. Nuclear Regulatory Commission has kept its messaging clear — there are no credible spent nuclear fuel canister breach mechanisms. But that is messaging geared for waving away the realistic radiological release estimates from an accident involving inevitable canister leakage assessment in its environmental impact statements. The reality is that the NRC knows

[9] Yucca Mountain Repository Project, Senate Hearing 109-523, May 16, 2006, https://www.govinfo.gov/content/pkg/CHRG-109shrg29473/html/CHRG-109shrg29473.htm

[10] In The Matter Of Private Fuel Storage L.L.C., Docket No. 72-22, November 14, 2005, Applicant's Response to State of Utah's Motion to Reopen the Record and to Amend Utah Contention Utah UU, Docketed USNRC. ML053260506.

that the thin-walled spent nuclear fuel canisters are highly susceptible to significant radiological leakage. They just don’t want you to know.

I think the NRC has a plan for what to do when any one of hundreds of spent fuel canisters has a leak. And that plan will be for people living near it, to evacuate.

Perhaps the other part of the plan is the usual ineffective radiological monitoring so that the full extent of the radiological release will be understated. When a nuclear reactor accident happens, environmental monitoring of the released radionuclides won’t be the responsibility of the nuclear plant owner. **State and federal radiological monitoring is designed to be inadequate, both during and after a radiological event.** Inadequate monitoring allows the nuclear industry to deny the extent of the release.

Despite the lies told about the Three Mile Island Unit 2 accident in 1979, lives were shortened by the accident. [11]The public was told that the release was very small. Too small to have caused the vomiting and hair loss that some people experienced. Too small to have caused the double-strand DNA breaks that some people would learn they had. People were lied to by the state officials as well as the NRC. (See 77 pages of the Three Mile Island “Incident” Chronology from 1979 to 2020 at NRC’s ML20106F218)

I don’t have reason to expect adequate or honest radiological monitoring now, some forty years after Three Mile Island. Detecting that a significant release occurred is possible, but estimating the magnitude of the release is difficult not only due to limited monitoring capability of the wind-blown radionuclides, it is also due to a desire by the nuclear industry to avoid admitting the full extent of a radiological release.

An operating reactor is required to have some monitoring equipment that can detect an abnormally high number of radioactive decays, and not be limited to a low and expected range of radioactivity. There are very few requirements for radiological monitoring of spent nuclear fuel canisters and the industry is working to reduce monitoring requirements. It means there will be substantial delay in detection as well as great ambiguity as to the full extent of the radiological release that is unfolding.

For environmental impact assessments and safety analyses, the NRC has limited its radiological consequences of spent fuel dry storage canisters to very small pinhole leaks. The assumed leak rates from a canister have been 1.58E-5 cm^3/s to 1.0E-4 cm^3/s. Such leaks are addressed in the environmental impact statement that was conducted for the proposed independent spent fuel storage installation at the Goshute Indian Reservation in Utah, the Private Fuel Storage facility (ML010330302).

The dry storage canisters in the U.S. are sometimes described as being below ground. But while some installations may be partially below grade, air flow around the metal canister must be

[11]Steve Wing, David Richardson, Donna Armstrong, and Douglas Crawford-Brown, A Reevaluation of Cancer Incidence Near the Three Mile Island Nuclear Plant: The Collision of Evidence and Assumptions, Volume 105, Number 1, January 1997, Environmental Health Perspective

maintained and there are large openings in the concrete installation to permit the needed air flow past the canister. From an independent fuel storage installation, any canister breach that releases radionuclides will release the radionuclides directly to the environment with no filtering.

These very small canister leaks stipulated by NRC's technically indefensible assumptions are estimated to yield very low radiation inhalation and external exposure doses at 500 meters from the canister installation. The NRC-licensees' estimated offsite radiation doses are typically less than about 15 mrem for the postulated very small canister leak and dominated by inhalation dose.

When the NRC accepted the safety analysis report for dry storage at the proposed Private Fuel Storage facility around 2000, the accident condition assessed in the safety analysis was a tiny leak rate from a dry storage canister. The basis for the tiny leak rate wasn't risk assessment, aging assessment, or technically justifiable. The tiny leak rate was borrowed from bolted lid transportation casks that had been recently leak tested, according to Marvin Resnikoff, who pointed out that assumed the tiny leak rate was inadequate to portray the radiological release from a canister in an accident, particularly if due to sabotage (see ML003686716).

But the view of the NRC was that the Private Fuel Storage facility was in a remote area, so it really didn't matter, despite being about 45 miles from Salt Lake City, Utah. (See the speech by Jeffrey Merrifield, NRC Commissioner in 2006 for various captured agency spin, ML060670032)

What are the canister leak consequences for a leak, even of modest size? The answer is, even using the NRC's fuel release fractions rather than the entire canister radionuclide inventory, the radiation dose within a few miles could be over several hundred rem. In other words, deadly. And if somehow, there is any radiological monitoring being conducted by someone (the NRC doesn't require it), you will be evacuating and not coming back to your home.

Typically,radiation monitoring won't be detecting much of the alpha particles that can be inhaled. So, typical monitoring following the accident will likely underestimate the inhalation dose that could be received. Even if soil samples are taken, the laboratories that provide the results typically are bought off by the nuclear industry to not report the results honestly and I see this occurs far more than people would think.

The radiological consequences evaluated in the 2008 Yucca Mountain License Application include analysis of a PWR canister accident inside a building with HEPA filtration. [12] The scenario of a breach of a spent nuclear fuel canister loaded with high burnup pressurized water reactor fuel assemblies was analyzed. The spent fuel involved in the scenario was a breached canister holding 36 PWR assemblies at 5 percent enrichment, 80 gigawatt-days/metric ton uranium (GWd/MTU), decay time of 5 years, per Appendix E of the 2008 YM Supplement. The

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[12] U.S. Department of Energy, Office of Civilian Radioactive Waste Management, *Supplemental Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*, Volume II, Appendices A through J, DOE/EIS-0250F-S1, June 2008. ML081750216.

scenario used fuel release fractions similar to those posed recently by the NRC in NUREG-2224. [13]

For a person exposed to the radiological release, located about 10 miles from the release (see wind direction and receptor location from Table B-2 of Appendix B of the 2008 YM Supplement) the 50th percentile dose was 2.4E-4 rem and the 95th percentile dose was 9.1E-3 rem. However, if the assumed 0.9999 effective HEPA filter performance is removed for volatiles and fuel fines, the doses would be a factor of 10,000 times higher: 2.4 rem (50th percentile dose) and 91 rem (95th percentile dose) at approximately 11 miles from the release point (see Appendix E of the YM 2008 Supplement).HEPA performance, in reality, is less effective than assumed. [14]

These doses, per arbitrary stipulation by the U.S. NRC is limited to a 30-day exposure. The 95th percentile dose would assume a premature death. The long-lived radionuclides would continue to poison the environment for all living creatures long after. The NRC terms the tritium, iodine-129 and krpton-85 to be gases, which would not be held up in HEPA filters, but are not the dominant contributors to dose. The inhalation dose is far higher than the external dose and is primarily due to the inhalation dose from but the radionuclides grouped as volatiles and fuel fines. The term "fuel fines" includes the plutonium, americium, curium and other radionuclides. The most recent fuel release fractions from NUREG-2224 are provided in Table 1. Estimated inhalation dose, unverified, is also provided in Table 1 and may be based on out-of-date dose conversion factors.

Table 1. Selected commercial spent nuclear fuel inventory in a canister.

Nuclide [a]	**Inventory per Assembly (Ci)** [b]	**Number of Assemblies**	**Release Fraction** [c]	**Release (Ci)**	**Eff DCF**[d] **(mrem/uCi)**	**Inhalation Dose at 500 m for 30 days (rem)**
Hydrogen-3	5.0E2	36	0.15 (gases)	2700	6.40E-2	0.11
Iodine-129	3.6E-2	36	0.15 (gases)	0.1944	1.74E2	0.02
Krypton-85	5.8E3	36	0.15 (gases)	31320	0	0
Cobalt-60	3.3E1	36	1 (crud)	1188	2.19E2	166.51
Strontium-90	6.5E4	36	3E-5 (volatiles)	70	1.3E3	58.24
Ruthenium-106	1.3E4	36	3E-5 (volatiles)	14	4.77E2	4.27
Cesium-134	4.1E4	36	3E-5 (volatiles)	44	4.6E1	1.29
Cesium-137	1.1E5	36	3E-5 (volatiles)	119	3.19E1	2.43
Barium-137m	9.9E4	36	3E-3 (fines)	10692	?	?

[13] U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguard, *Dry Storage and Transportation of High Burnup Spent Nuclear Fuel*, NUREG-2224, November 2020. https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML20191A321

[14] A. Duncan and M. Kane, Savannah River Plant, *Properties and Behavior of 238Pu Relevant to Decontamination of Building 235-F*, SRNL-STI-2009-00239, June 2009. http://www.osti.gov OSTI ID: 969795.

Nuclide [a]	Inventory per Assembly (Ci) [b]	Number of Assemblies	Release Fraction [c]	Release (Ci)	Eff DCF[d] (mrem/uCi)	Inhalation Dose at 500 m for 30 days (rem)
Plutonium-241	8.0E4	36	3E-3 (fines)	8640	8.25E3	45,619
Yttrium-90	6.5E4	36	3E-3 (fines)	7020	8.44	37.9
Promethium-147	2.3E4	36	3E-3 (fines)	2484	39.2E1	623
Europium-154	6.2E3	36	3E-3 (fines)	669.6	2.86E2	122.5
Curium-244	1.4E4	36	3E-3 (fines)	1512	2.48E5	239,985
Plutonium-238	6.8E3	36	3E-3 (fines)	734	3.92E5	184,146
Antimony-125	1.9E3	36	3E-3 (fines)	205.2	1.22E1	1.6
Europium-155	1.8E3	36	3E-3 (fines)	194.4	4.14E1	5.15
Americium-241	8.8E2	36	3E-3 (fines)	95.04	4.44E5	27,007
Plutonium-240	4.0E2	36	3E-3 (fines)	43.2	4.29E5	11,861
Plutonium-239	1.8E2	36	3E-3 (fines)	19.44	4.29E5	5337
					Total (rem) At 500 m for 30 days, Inhalation dose	~400,000 rem

a. The list of radionuclides is incomplete and only includes some of the radionuclides typically contributing the most to radiation dose.

b. Inventory per assembly based on Yucca Mountain Supplement 2008, Appendix E at ML081750216. The number of pressurized water reactor assemblies involved was 36 PWR assemblies, at 5 percent enrichment, 80 gigawatt-days/metric ton uranium (GWd/MTU), and decay time of 5 years, per Appendix E of the 2008 YM Supplement.

c. Release fractions based on U.S. NRC, Dry Storage and Transportation of High Burnup Spent Nuclear Fuel, NUREG-2224, November 2020, ML20191A321, Table 3-1, for “accident-fire conditions.” There are many variations in the release fractions used in past radiological release evaluations. (The release fraction for gases (0.3), volatiles (2E-3), fuel fines (2E-3) had been assumed for oxidation release in DOE-RW-0573, Rev. 1, for high burnup fuel.)

d. The effective dose conversion factors (mrem/microcurie) are from 1999 and somewhat out of date, from a Private Fuel Storage analysis, ML010330302. Chi/Q for 500 meters is multiplied by breathing rate, 1.94E-3 (s/m^3) * 3.3E-4 (m^3/s) = 6.4E-7 must be multiplied by the curies inhaled and the effective dose conversion factor.

e. The YM Supplement does not reveal the atmospheric dilution factor used for the 11 mile dose (10,200 meters), nor were the documents cited as source documents actually revealing the atmospheric dilution factor, the Chi/Q for the public dose. (ML-90770783 did not include the public and ML090770554 available online was incomplete.) ML092360330 gives the distance to the public but not the atmospheric dilution factor, which the Department of Energy appears to go to great lengths to avoid revealing. The 2007 Bechtel SAIC report, 000-00C-MGR0-02800-000-00B is not found on NRC’s Adams database. Also, according to the YM Supplement, the 95th percentile dose for a noninvolved worker for the canister scenario, Table E-11, is inexplicably lower than the 50th percentile dose. This appears to be an error. But for the 50th percentile dose, no exposure time or dilution factor given, the dose was 0.21 rem. Removing the HEPA filters would yield a 2100 rem dose to the noninvolved worker. The doses to the involved workers or workers deemed close to the canister accident are not given. In any case, a 500 rem dose is acknowledged to kill 50 percent of people in short order and based on the experience of SL-1 emergency responders said to have received 20 rem doses, the other 50 percent are not going to live more than a few years.

Of course, ideally, a person would not stand in the radiological plume 500 meters from the canisters for 30 days. But the U.S. NRC has been eliminating requirements for canister monitoring and capability for emergency response. Also, the respirable fraction is assumed to be 1.0, consistent with Department of Energy assumptions for high burnup fuel. [15]

The acutely high doses in Table 1 give an explanation as to why the NRC refuses to admit that a canister leak of significant size is credible. There is no way that an environmental impact statement could yield an acceptable result if the NRC was truthful. And the full extent of the damage to the fuel in the canister as the fuel oxidizes over time will "unzip" the cladding and allow fuel pellets to relocate inside the canister. This also makes the criticality risk higher, should a moderator (such as water) enter the canister.

Unlike the radiological consequence evaluation from the 2008 YM Supplement, most NRC radiological release evaluations, assume that the canister leak is very small, releasing only a fraction of the releasable material from the canister and the inhalation continues for 30 days. The duration of 30 days is stipulated by the NRC on the basis that actions will be taken within 30 days to terminate the release.[16] But there is no technically valid basis for concluding that any action can be taken to terminate the release because there is no technology to repair a canister containing spent fuel and no means for removing the spent fuel from the canister. There is no means developed to place a leaking canister into a sealed confinement such as a cask. Nor is there capability to provide adequate heat transfer for the long term with a container-in-a-container approach.

As oxygen enters the canister, any cladding damage will allow the uranium to oxidize. The uranium fuel matrix will swell, further damaging the cladding. It is not clear that NUREG-2224 fuel release fractions are adequate.

For Yucca Mountain evaluations, canister leakage from outdoor storage of dry canisters was not evaluated despite the long-term storage of a high number of canisters to allow additional cooling of the canister to limit the thermal loading of the repository.

For Yucca Mountain evaluations, the radiological releases from spent fuel were assumed to occur inside buildings with highly effective HEPA filters, that were assumed to be 0.9999 effective. With the dose evaluated to a receptor (the location of the maximally exposed individual) located miles from the facility, the estimated doses remained less than one rem, but only by ignoring realistic unfiltered radiological release scenarios.

The Department of Energy's estimated Yucca Mountain pre-closure radiological doses and the NRC's independent fuel storage installations are stated to have low radiological doses. **But the reality is that these agencies excel at whittling down the radiological doses on paper,**

[15] Department of Energy, Yucca Mountain Repository SAR, Docket No. 63-001, DOE/RW-0573, Rev. 1, https://www.nrc.gov/docs/ML0907/ML090700894.pdf Ch 1.6, Page 1.8-18 [286]

[16] U.S. Nuclear Regulatory Commission, Interim Staff Guidance – 5, Revision 1, Confinement Evaluation, See Attachment to ISG-5 Revision 1, page 11 https://www.nrc.gov/reading-rm/doc-collections/isg/isg-5R1.pdf

while actually exposing the public to much higher, and sometimes lethal, potential accident radiological release doses with their proposed facilities.

Surplus Weapons Plutonium Slated for WIPP

In a decision made last August, the Department of Energy has slated 7.1 metric tons of surplus pit plutonium for disposal at the Waste Isolation Pilot Plant (WIPP) in New Mexico.[17]The DOE hopes to dispose of an addition 34 metric tons of surplus plutonium at WIPP.

This is in addition to the plutonium already disposed of at WIPP, estimated at 5.36 metric tons as of September 30, 2019, according to a National Academy of Sciences report.

The National Academies of Sciences (NAS) released a review of the DOE's surplus weapons plutonium disposal plan last May. [18][19]**The NAS found that disposal of the surplus weapons plutonium at WIPP "would fundamentally change the nature of the geologic repository, which raises social, environmental, and technical questions."**

The surplus weapons plutonium will require down-blending (or diluting), which could take place at the Savannah River Site or at Los Alamos National Laboratories (LANL) in New Mexico, prior to disposal at WIPP.

The U.S. government has an agreement with the Russian Federation, the Plutonium Management and Disposition Agreement (PMDA), requiring each country to dispose of 34 metric tons of surplus plutonium by blending the plutonium with uranium oxide to make "mixed oxide" MOX fuel to be used in nuclear reactors. But the MOX fuel fabrication facility under construction in South Carolina at the Savannah River Site was canceled due to escalating construction costs and lack of any U.S. utility wanting the MOX fuel.

The plan to dilute and dispose of 34 metric tons of surplus plutonium at WIPP is estimated to take 31 years and $18.2 billion to complete. But despite being considered a viable solution, the NAS report highlighted concerns over not meeting the requirements for plutonium disposition as agreed to with Russian, statutory and expansion of physical capacities at WIPP, and the life extension needed for WIPP. It is also a concern that the dilution processes have not been demonstrated at the scale that will be required. And the security requirements to verify disposal of the weapons plutonium have not been developed.

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[17] Adrian Hedden, *Carlsbad Current-Argus*, "Department of Energy: Waste Isolation Pilot Plant to receive down blended weapons-grade plutonium," September 15, 2020. https://www.currentargus.com/story/news/local/2020/09/15/doe-sending-more-nuclear-waste-wipp-new-mexico-carlsbad/5768537002/

[18]*National Academies: Disposing of surplus plutonium at WIPP viable*, webpage, May 4, 2020, https://www.ans.org/news/article-142/national-academies-disposing-of-surplus-plutonium-at-wipp-viable/

[19]*The National Academies of Sciences, Engineering and Medicine*, "Review of the Department of Energy's Plans for Disposal of Surplus Plutonium in the Waste Isolation Pilot Plant," April 2020. https://www.nap.edu/catalog/25593/review-of-the-department-of-energys-plans-for-disposal-of-surplus-plutonium-in-the-waste-isolation-pilot-plant

The NAS report (Chapter 5.2) acknowledged that the Department of Energy had included disposal of surplus weapons plutonium in the inventory for the environmental assessments of Yucca Mountain, in the form of MOX and/or vitrified high-level waste. And that the DOE had announced its deep borehole disposal demonstration program, also discussed for plutonium disposal, was terminated in 2017.

Assessment of the capacity of WIPP to confine the waste is expected to be managed by Sandia National Laboratory. This is the laboratory that finagled the models of radiological releases so successfully for the Yucca Mountain License Application to the U.S. Nuclear Regulatory Commission.

For the disposal of spent nuclear fuel, high-level waste and surplus plutonium slated for the Yucca Mountain repository, there were years of hand-wringing over the difficulty of meeting post-closure radiation dose limits from the trickle-out of groundwater laden with radionuclides from the dissolving radioactive waste.

But something would happen to drastically lower the Department of Energy's trickle out problem and radiation doses between 2007 and 2008 when the DOE submitted its license application for Yucca Mountain to the NRC. I had trouble understanding how the predicted doses dropped from a couple hundred millirem to less than 1 mrem/yr for post-10,000-year time frame. Both the earlier and later submittals had assumed perfect titanium drip shield performance, despite the implausibility of ever installing them in the repository.

The problem of the estimated high radionuclide trickle out from Yucca Mountain ended when Sandia took over the modeling of radionuclide trickle out and squashed the assumed water infiltration rates through the proposed Yucca Mountain repository. **A review of Sandia's modeling for Yucca Mountain that yielded estimates of low radiation doses from water contamination from the trickle out of radionuclides found that the Sandia models were technically indefensible**. [20]

That independent review of DOE's calculations had been contracted by the DOE but withheld from the State of Nevada. The review's conclusion was that the Department of Energy's modeling of water infiltration to the disposed of waste **did not provide a credible representation of water infiltration at Yucca Mountain**.

In other words, because the periodic spikes in water infiltration had raised the estimated radiation dose, the water infiltration spikes were simply removed from the modeling in order to drive the estimated radiation exposures down. The contamination trickle-out problem that had previously estimated 95th percentile radiation doses above 1000 mrem/yr (yes, one thousand mrem/yr) and would struggle to meet the 100 mrem/yr median requirement by EPA regulations

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[20]Senate Hearing 109-523, Yucca Mountain Repository Project, May 16, 2006. https://www.govinfo.gov/content/pkg/CHRG-109shrg29473/html/CHRG-109shrg29473.htm

now had contrived the modeling to slash the estimated radiation dose to a person living 15 km (or 11 miles) downgradient to less than 1 mrem/yr. [21]

And the other problem that the Department of Energy made disappear, with regard to the disposal of surplus plutonium at the proposed Yucca Mountain Repository, was that of criticality concerns.

The Department of Energy's originally envisioned inventory for Yucca Mountain had included 2 percent enriched commercial spent nuclear fuel and the residual vitrified waste from reprocessing at West Valley. It was expanded substantially when the Navy ceased reprocessing the high enriched naval and DOE research fuels by 1992 and it meant that now these fuels would require disposal. And it was another substantial change when the DOE identified the surplus weapons plutonium, potentially for disposal at Yucca Mountain.

Two scientists from Los Alamos National Laboratory would explain how the plutonium-239 posed a particularly high criticality risk at Yucca Mountain. [22][23] The Department of Energy has continued to argue that while criticality is possible at Yucca Mountain, it is sufficiently unlikely and of unimportant consequence if it does occur. [24]But the risk of criticality posed by the disposal of surplus weapons plutonium (and spent nuclear fuel) at Yucca Mountain is substantial and not to be casually dismissed, no matter how emphatically the DOE tries to arm-wave the risk away. And in addition, the criticality risks remain after 10,000 years, yet there is no regulatory requirement to assess or limit the criticality risk after 10,000 years, either at Yucca Mountain or WIPP.

The disposal of surplus weapons plutonium at WIPP, perhaps up to 48.2 metric tons of plutonium, has caused a renewed look at the potential for criticality accidents at WIPP and more detailed assessment than the sweeping screening arguments used for WIPP in the past. New criticality safety assessments for WIPP have noted that measures such as boron carbide additives or load management may be needed for the disposal of surplus weapons plutonium, yet there has been little transparency or scrutiny of the criticality assessments. Complicating the problem is that WIPP drums are known to be overloaded with more plutonium (and fissile gram equivalents) than is officially assumed and this was verified by the extensive contamination caused by explosion of a single drum in 2014.

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[21]Letter from Council for the State of Nevada to Secretary of the U.S. Nuclear Regulatory Commission, State of Nevada's Supplement to its June 4, 2008 Petition Asking the NRC to Reject DOE's Yucca Mountain License Application as Unauthorized and Substantially Incomplete, July 21, 2008. The letter cites the review of DOE's infiltration model performed at DOE's request by ORISE (Oak Ridge Institute for Science and Education). ORISE provided the results of this independent review to DOE on April 30, 2008. http://www.state.nv.us/nucwaste/news2008/pdf/nv080721nrc.pdf

[22] C. D. Bowman and F. Venneri, Los Alamos National Laboratory, *Underground Autocatalytic Criticality from Plutonium and Other Fissile Material*, LA-UR 94-4022, 1994.

[23] C. D. Bowman, Los Alamos National Laboratory, *Underground Supercriticality from Plutonium and Other Fissile Material*, LA-UR-94-4022A, 1994.

[24] Rob P. Rechard et al., Sandia National Laboratory, *Consideration of Criticality when Directly Disposing Highly Enriched Spent Nuclear Fuel in Unsaturated Tuff: Bounding Estimates*, May 1996.

The tendency for the Department of Energy to force its repository performance analyses and criticality analyses to obtain the desired answers for both pre-closure and post-closure assessment, which it did to a technically unjustifiable extent for the Yucca Mountain License Application to the NRC, means that the State of New Mexico must insist on a very thorough and independent review of the proposed expanded WIPP mission.

Articles by Tami Thatcher for January 2021.