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Remembering Whistle-Blower Karen Silkwood and a Look at Her Plutonium Intake

I was reminded of Whistle-Blower Karen Silkwood when Kitty Tucker, wife of Robert Alvarez, died March 30 at the age of 75. Kitty will be greatly missed and is remembered as a "force of nature" and for her championing many causes, including helping to raise national awareness of the case of Karen Silkwood. [1]

Karen Silkwood was an employee of Kerr-McGee's plutonium fuels production plant in Crescent, Oklahoma. Silkwood died November 13, 1974 in a mysterious car crash on her way to meet with New York Times reporter David Burnham to discuss safety problems and missing plutonium at the plant. The papers she was to show the reporter were never found. The Kerr-McGee plant soon closed. In 1983, the well-known movie "Silkwood" was made.

Silkwood was a worker who helped to fabricate plutonium pellets using a glove-box. She was troubled by safety problems at the plant. In November, prior to her death, Silkwood was found to have excessive and unexplained plutonium contamination. She was then required to provide nasal swabs, urine and fecal samples for several days for bioassay to measure plutonium excretion, and she had a lung count performed before she died.

Silkwood's plutonium contamination was not from any known routine or incident exposure. Her employer tried to blame Silkwood for intentionally contaminating herself. But that seems unlikely given that Silkwood hoped to have children and was concerned about the health hazards of plutonium.

Aa article by Los Alamos describes the plutonium contamination found before Silkwood's death and found by autopsy. [2] In the weeks before her death, extremely high levels of plutonium contamination were found on her body and also in her apartment. The levels of plutonium contamination stated in the Los Alamos article include extremely high nasal swab results of 45,000 disintegrations per minute (dpm) (or about 20 nanocuries) in each nostril on November 7, 1974.

I wrote last month that nasal swab radioactive decay counts can be used to provide a rough estimate of the lung intake. The nasal swab result in disintegrations per minute (dpm) for each nostril are summed and then most guidance suggests that the nasal swab result is 5 or10 percent

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[1] Katharine Q. Seelye, *The New York Times*, "Kitty Tucker, 75, Who Raised Awareness of the Silkwood Case, Dies," April 11, 2019. https://www.nytimes.com/2019/04/11/obituaries/kitty-tucker-dead.html

[2] *Los Alamos Science,* Los Alamos National Laboratory, "Radiation Protection and the Human Radiation Experiments," "The Karen Silkwood Story: What We Know at Los Alamos," Issue Number 23, 1995. Starting p. 252. https://library.lanl.gov/cgi-bin/getfile?00326645.pdf

of the inhalation, to provide a rough idea of the intake. At 20 nanocuries on each nasal swab, the total for both nostrils would be 40 nanocuries. Assuming that this result was 10 percent of her lung intake would indicate that her lung intake could be roughly 400 nanocuries which far exceeds the limit at the time for allowable lung burden (16 nanocuries). The lung count she had while alive reported 6 to 7 nanocuries of plutonium-239 in her lungs.

This nasal swab estimate assumes that all the decays are from plutonium-239, which overstates the Pu-239 somewhat because other plutonium isotopes like plutonium-241 and its decay product americium-241 would also be present. Plutonium that is fresh, however, has relatively low buildup of americium-241.

One fecal sample was reported at 40,000 dpm which is equivalent to 18 nanocuries. Her bed sheets were between 500 and 2,000 dpm. Contamination in her apartment was as high as 400,000 dpm (180 nanocuries) on a package of bologna in the refrigerator. She routinely used a lunch box to take to work and she had returned uneaten food to the frig from the lunch she had taken to work but had not finished on November 5.

The Los Alamos report states that "between October 22 and November 6, high levels of activity had been found in four of the urine samples that Silkwood had collected at home (33,000 to 1,600,000 dpm) whereas those that were collected at the Kerr-McGee plant or Los Alamos contained very small amounts of plutonium if any at all." The report seems to try to imply that her urine samples were actually low and those taken at home merely contaminated by the contamination in her apartment or lunch pail. The dates and detailed sample results are not provided. Low urine sample results prior to her intake are not relevant. It looks like someone added to her lunch, invisible yet enormous amounts of plutonium, which could have been obtained from glove box operations. Her lunch box would likely have been in an unattended refrigerator much of the time when she's at work.

Silkwood was given a lung count prior to her death to estimate the amount of plutonium in her lungs. The lung count measured the amount of americium-241 in her lungs, and based on the expected ratio of Am-241 to plutonium-239 in the material she was exposed to, the amount of Pu-239 in her body was limited to what was found in her lungs, estimated as 6 or 7 nanocuries of Pu-239. But then, like now, lung count results have a variety of ways of being unreliable, either because of equipment, methodology or deliberate manipulations. In the 1970s, the permissible lung burden for nuclear workers was 16 nanocuries for a roughly 5 rem annual dose. The entire intake of plutonium and its spread of plutonium throughout her body was not measured or estimated while she was alive. And her nasal swabs indicated that the lung intake would be far higher, on the order of 400 nanocuries.

The total amount of plutonium in Silkwood's apartment was estimated at 300 micrograms. The amount of plutonium-239 expressed in grams, 300 micrograms, is equivalent to an activity of 18,615 nanocuries. The conversion of units from weight (i.e., in micrograms) to activity (i.e. in nanocuries) is radioisotope specific. [3] It can be performed using an online calculator such as RadPro Calculator. [4]

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[3] Units: 1 microgram is 1.0E-6 grams. 1 nanocurie is 1.0E-9 curies. The Los Alamos report uses a typical array of units in describing the plutonium intake which can be confusing. The intake may be expressed in nanocuries of americium-241 — this may then be used to estimate the plutonium-239 intake based on the composition of the material inhaled. The weight in micrograms may be used to express the amount of plutonium-239 rather than

Following Silkwood's death, at the request of the Oklahoma State Medical Examiner and the Atomic Energy Commission, and with permission from her father, an autopsy was performed that included assessment of her radiological uptake by a team from Los Alamos. The autopsy found that her lungs contained 4.5 nanocuries of plutonium-239 and her liver contained 3.2 nanocuries of plutonium-239. The Los Alamos report then concludes that her in vivo lung count results of 6 or 7 nanocuries agree with the total lung and liver result from the autopsy. Yet the autopsy lung count was without bone and muscle shielding and its impact adjusted for in ways that are not explained. Also, the 40,000 dpm (equivalent to 18 nanocuries of Pu-239, neglecting the radioisotopes that other than Pu-239) in the one fecal sample are ignored in the Los Alamos article/report conclusions or assumed to have had zero plutonium absorption into the bloodstream.

Nasal swab, lung count, urine and fecal bioassay for Karen Silkwood are summarized in Table 1.

Table 1. Karen Silkwood's plutonium internal and bioassay contamination data.

Sample	Plutonium-239, nanocuries	Alternate Units and Notes
Nasal swipe, November 5	(0.072 nanocuries in each nostril)	160 disintegrations per minute, dpm, each nostril
Nasal swipe, November 7	(20.3 nanocuries in each nostril, for a total of 40.6 nanocuries)	45,000 dpm, each nostril Usually a rough estimate of an intake is the nasal result times 10. In this case, 406 nanocuries.
Fecal sample, November 7	(18 nanocuries)	40,000 dpm
Urine samples, October 22 through November 6	(0 nanocuries) (14.9 to 720.7 nanocuries)	Little to no contamination in urine samples collected at the Kerr-McGee plant or after death. 33,000 to 1,600,000 dpm at home Possible external contamination of the urine or sample bottles.
In vivo Lung count, November 11, total for both lungs	6 – 7 nanocuries Pu-239 (0.34 nanocuries Am-241)	

activity in nanocuries. The disintegration per minute (DPM) from bioassay sampling may be provided all without stating the combination of radionuclides or their activity in curies.

[4] Convert weight to activity for plutonium-239 and disintegrations per minute to activity using Rad Pro Calculator at http://www.radprocalculator.com/Grams.aspx and http://www.radprocalculator.com/Conversion.aspx

Autopsy Lung count, for both lungs.	4.5 nanocuries Pu-239	An unstated adjustment for lack of bone and muscle shielding is used.
Autopsy Liver result	3.2 nanocuries Pu-239	
Autopsy Bone result	Approximately 0	This low uptake by bone is an odd result and the use of a small bone tissue sample and overall methodology is not explained.

Table notes on radioactivity units for plutonium-239:

1 becquerel (Bq) is equal to 1 [radioactive decay] disintegration per second (dps);

1 dps is equal to 60 disintegrations per minute (dpm);

1 becquerel (Bq) is equal to 3.7E10 curies (Ci);

60 dpm = 1 dps = 2.7027E-11 curie = 2.727E-5 microcurie = 0.027027 nanocuries;

1000 dpm = 0.45045 nanocuries (nCi);

1 microcurie is 1.0E-6 curies; 1 nanocurie (nCi) is 1.0E-9 curies;

1 picocurie (pCi) is 1.0E-12 curies; and

1 microgram of Pu-239 is equal to 62 nanocuries (nCi) of activity noting that the conversion from grams to curies requires that the specific radioisotope conversion factor be used.

If Silkwood's urine results were actually very low and that the high sample results were primarily due to sources of contamination from her home, that would suggest that any ingested plutonium largely traveled through the digestive tract without being absorbed into the blood stream and that any inhaled plutonium stayed in her lungs. **How, then, did plutonium arrive in her liver?**

The Los Alamos autopsy says a small bone tissue sample indicated that she had minimal bone dose — which is odd given the transport of plutonium to her liver and the high uptake of plutonium in bone when plutonium is in the blood stream.

The Los Alamos article leaves many questions unanswered as it seems to downplay Silkwood's overall ingestion and inhalation plutonium intake and whole-body dose. Los Alamos also had "skin in the game" because finding a higher intake in the autopsy than Dr. George Voelz of Los Alamos had assured Silkwood when she was alive would have meant his previous estimate communicated to Silkwood had been incorrect and had significantly underestimated her intake.

There are plenty of irregularities in the Los Alamos explanation of Silkwood's plutonium intake and I see many reasons to think that participants from Los Alamos may not have been unbiased and may have grossly underestimated Silkwood's plutonium intake.

Defense Nuclear Facilities Safety Board Finds Transuranic Waste Drum Explosion Hazards *Still* Not Adequately Mitigated by Fluor Idaho and the Department of Energy

Although the Department of Energy didn't discuss it at the April Idaho Cleanup Project Citizens Advisory Board meeting, the Defense Nuclear Facilities Safety Board (DNFSB) has found that neither the Department of Energy nor its Idaho Cleanup contractor, Fluor Idaho, have yet developed adequate protections for waste drum explosion hazards. The waste drums typically contain transuranic radionuclides but can also contain radioactive uranium and fission products as well as chemical waste.

In a report transmitted March 12, 2019, the DNFSB stated that **"DOE-ID lacks effective controls to prevent or mitigate deflagrations in drums of repackaged waste."** [5] The report details why the Department of Energy's response to understanding how to prevent future transuranic waste drum explosions remains inadequate, and why the new mitigations put in place are inadequate. The DNFSB found that Fluor Idaho's limited mitigations, which included the use of thermal monitoring during and immediately following repackaging and a 24 hour hold time after sorting the waste prior to repackaging, do not provide adequate hazard protection.

Drum over-pressurization that forcefully ejected the lids from four drum last April at the Idaho National Laboratory's Radioactive Waste Management Complex, can also be described as explosions or as deflagrations. No matter what it is called, the DNFSB found that the DOE's response and its safety analyses that are supposed to protect workers and the environment have been and still remain inadequate. Last fall, U.S. Department of Energy cleanup contractor Fluor Idaho issued a report on the causes of the explosion of the four waste drums last April. [6]

A meeting is to be held in Washington D.C. on May 22 to discuss how DOE plans to provide technically sound assumptions regarding excessive gas buildup in waste drums that exceeds what drum vents are capable of providing. The DNFSB found that the Department of Energy and its contractors have continued to make incorrect assumptions about gas buildup, the likelihood and consequence of drum explosions, and the efficacy of certain mitigative measures. The DNFSB found that DOE Standard 5506-2007, *Preparation of Safety Basis Documents for Transuranic (TRU) Waste Facilities*, contains assumptions that are not technically supported and actually promotes inadequate safety analysis by not requiring technical analysis when it is needed.

DOE-ID had continued to assume that drum explosions were "extremely unlikely" despite discovering high levels of methane in nine drums in 2012. Had DOE-ID and its contractor correctly declared then that the condition indicated inadequate safety analysis, appropriate investigations could have been conducted. Only by the explosion of the four drums in April 2018 have Fluor Idaho and DOE-ID admitted that the likelihood of drum explosions is "anticipated" not "extremely unlikely." More hazard mitigation is required to address higher

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[5] Defense Nuclear Facilities Safety Board, Letter to Secretary of Energy, March 12, 2019 with attached staff report "Idaho Waste Drums with Elevated Methane Concentrations," See dnfsb.org or https://ehss.energy.gov/deprep/2019/FB19M12A.PDF

[6] 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

likelihood and high consequence accidents and for a broader range of gas generation events, not just for drums with beryllium-carbide immediately following repackaging. All drums with carbide metals or unreacted uranium and during storage, not just soon after repackaging, require more hazard analysis and mitigation.

The four drums that exploded inside Accelerated Retrieval Project V (ARP V) last April could have had serious environmental consequences by causing a significant release to the environment because drums could have been stored in a building with no filtered confinement system or outside confinement when they exploded. Exploding drums also pose the risk of serious injury to workers and emergency responders.

Dozens of possible chemicals were ascribed to a catch-all category SD-176 for powdery material considered "homogeneous solids" of the kind from Rocky Flats nuclear weapons plant where Portland cement-like material had been added to drums with various chemical and finely divided radionuclide and metal wastes. [7]

No analyses were conducted for chemical compatibility and reactive and pyrophoric materials for the SD-176 waste as required by hazardous waste RCRA laws. On top of that, no nuclear safety analysis was conducted to mitigate the hazards of this new SD-176 waste stream.

The day of the explosion of four waste drums, uranium from one drum was mixed with the unknown material in other drums to distribute the uranium among the drums. Now supplied with oxygen from the repackaging, the uranium began oxidizing and heating up the drums. The heat enabled another chemical reaction that rapidly produced methane from the beryllium carbide [8] in the drums.

The DOE also violated its radioactive waste management regulations by not having a plan for disposing of the waste prior to processing it. Current Waste Isolation Pilot Plant (WIPP) waste acceptance criteria were not being applied. [9]

DOE regulations and state and federal laws were ignored in order to save money and time in the processing of the radioactive and chemically hazardous waste. In Idaho, the DOE-ID, Fluor Idaho and the Idaho Department of Environmental Quality have all pretended that the waste was

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[7] Idaho Completion Project, Bechtel BWXT Idaho, LLC for the Department of Energy, "Historical Background Report for Rocky Flats Plant Waste Shipped to the INEEL and Buried in the SDA from 1954 to 1971," ICP/EXT-04-00248, Revision 1, March 2005. https://ar.icp.doe.gov/images/pdf/200504/2005040400022KAH.pdf

[8] U.S. Nuclear Waste Technical Review Board, "Management and Disposal of U.S. Department of Energy Spent Nuclear Fuel – Report to the United States Congress and the Secretary of Energy," December 2017. http://www.nwtrb.gov/our-work/reports/management-and-disposal-of-u.s.-department-of-energy-spent-nuclear-fuel-(december-2017) On p. 22 of this report, the NWTRB states that "Carbide-containing DOE SNF can create combustible gases such as methane and acetylene when contacted by water …if the coatings on the carbide particles are damaged." While what was in the transuranic (or uranium) waste drums was not spent nuclear fuel, the knowledge of potential reactions with carbide are well-known and yet no identification of this hazard was conducted for the waste being treated which they knew potentially contained beryllium carbide from Rocky Flats weapons production processes — that's likely why the uranium had not be "roasted."

[9] Department of Energy, Carlsbad Field Office, WIPP Waste Acceptance Criteria, DOE/WIPP-02-3122, Revision 8 Effective July 5, 2016. http://www.wipp.energy.gov/library/cra/CRA-2014/references/Others/US_DOE_2002_WIPP_Rev_6_TRU_Waste_Acceptance_Criteria_02_3122.pdf

being treated in accordance with laws and regulations. But it wasn't. [10] [11] Idaho DEQ has indicated that enforcement actions in regard to the four drums that exploded last April are pending.

In 2012, nine drums were found to have excessive levels of methane gas in them that could not be shipped to WIPP. The reasons for the gas buildup in the waste drums, the unexpected trends in the methane gas, and the strategies for managing these drums still lack adequate technical basis and lack adequate safety analysis. Gas monitoring typically is not conducted until the drums are ready to be shipped to WIPP and is not required for drums shipped to other disposal facilities such as the one in Clive, Utah.

The repackaging of drums which increases oxygen levels can result in rapidly increasing methane buildup in drums containing beryllium carbide or other metal carbides, but neither drum sampling nor historical knowledge of what is in the drums have identified the amount of carbide metals. Gas buildup monitoring in the problem drums continued to rise in ways that were not predicted for many days.

The DNFSB report noted on page 7 that "re-arranging or disturbing the waste could renew a methane-generating reaction that had been slowing down." I still am concerned that emergency response considerations are inadequate for accidental puncture of a drum that could also allow increases in oxygen and allow rapidly increasing methane buildup.

The DNFSB found that the Department of Energy missed several opportunities to recognize and prevent drum explosions: the drum explosion at the Waste Isolation Pilot Plant in 2014, and drum fires at the Idaho National Laboratory in 2005 during exhumation at the Radioactive Waste Management Complex Subsurface Disposal Area and in 2017 at the Advanced Mixed Waste Treatment Project.

Based on the DNFSB report and on information presented at Idaho Cleanup Project Citizens Advisory Board meetings, here's what I conclude: **The Department of Energy's narrow review of fire and explosion incidents has paved the way for more drum accidents at the INL and around the DOE Complex. The reduction in the number of drums handled as planned cleanup winds down could leave a higher number of problem drums and even further reduced attention to safety issues than the inadequate hazard mitigation today.**

DOE-ID had hoped that it would be satisfactory to "grandfather" already packaged drums to older WIPP Waste Acceptance Criteria. DOE-ID has only recently been acknowledged at the April Citizens Advisory Board meeting that Idaho's drums will be required to meet the most recent WIPP Waste Acceptance Criteria, but the impacts of this were not explained.

At the Idaho National Laboratory, while the number of total number of drums is reduced as drums are shipped to WIPP, *known problem drums* that don't meet WIPP Waste Acceptance

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[10] For more about the April transuranic waste drum ruptures at the Radioactive Waste Management Complex at the Idaho National Laboratory Idaho Cleanup Project, see past EDI newsletters on the April drum ruptures (May through November 2018) and my second Public Comment submittal on October 30 to the Idaho DEQ concerning renewal of the Advanced Mixed Waste Treatment Project RCRA permit renewal at www.environmental-defense-institute.org

[11] DOE Order 435.1, "Radioactive Waste Management," DOE Order 830 "Nuclear Safety Management" (contains hazard identification and Unreviewed Safety Question requirements) and federal and state Resource Conservation and Recovery Act (RCRA) laws.

Criteria as well as *problem drums not yet known to have problems*, remain in Idaho and *still* lack adequate hazard mitigations. As the number of waste drums and the number of employees drop Fluor's waste drum operations, the risk of more drum accidents may not be dropping. And if Fluor Idaho is replaced by another cleanup contractor, cost pressures could continue to allow more waste drum accidents.

Highlights of the Idaho Cleanup Project Citizens Advisory Board Meeting April 25 Meeting

The Idaho Cleanup Project Citizens Advisory Board meeting held April 25 in Twin Falls was rather predictable: [12]

- **The Integrated Waste Treatment Unit (IWTU) is continuing to struggle to commence operations.** There is progress toward radiological hot operations and the special emissions testing needed for state air permitting. Once operating, 900,000 gallons of liquid sodium-bearing waste in three tanks will be converted into a highly soluble granular powder that will be stored on site pending **final disposition** — which DOE is making no actions to obtain. The total project cost is yet to be known but it far exceeds initial estimates. The chemical and radiological composition of each of the three tanks is somewhat variable and strategies to mix or not mix waste from different tanks together have been evolving. Further testing at the Hazen facility in Colorado is planned in order to address differences in the waste composition in each tank. Details about radiological emissions monitoring that will be conducted during the initial phase of hot operations are not available, nor are details about the radiological emissions monitoring that will be conducted during routine operations.
- It is expected that there will be eight years of winding down for the transuranic waste shipments of waste stored above ground and the targeted chemically-laden waste still being exhumed. The amount of transuranic waste remaining buried over the Snake River Plain aquifer is never mentioned because most of the buried transuranic waste is remaining buried as only chemically laden wastes are "targeted" and removed (see our next article). The facilities are covered by an interim status permit. Phase 2 will close treatment buildings Phase 3 will close all remaining buildings with all the waste has left the state. DOE had hoped to "grandfather" the waste into an older revision of the Waste Isolation Pilot Plant (WIPP) Waste Acceptance Criteria, but WIPP wants Idaho to meet current WIPP Waste Acceptance Criteria. There was no presentation discussing the presence of problem drums or inadequate safety analysis and hazard mitigation of gas buildup in drums, as identified by the Defense Nuclear Facilities Safety Board in March.
- Yucca Mountain spent fuel and High Level Waste (HLW) repository status is gloomy and despite former Federal Nuclear Waste Negotiator and former State Senator Richard Stallings' presentation, the process for licensing a permanent repository or interim storage remains largely unexplained to CAB members. Stallings sees Yucca Mountain

[12] Idaho Cleanup Project Citizens Advisory Board (ICP CAB) at https://www.energy.gov/em/icpcab/idaho-cleanup-project-citizens-advisory-board-icp-cab and also see recently answered questions at https://www.energy.gov/em/icpcab/recently-asked-questions

technical challenges as insurmountable while favoring interim storage and eventual reprocessing. The waste disposal issues and environmental releases involved with spent nuclear fuel reprocessing and the technical safety issues involved with long-term interim storage don't seem to be fully appreciated by Stallings.

- The DOE is expected to act on its proposed reinterpretation of HLW but what it will do and when, remain a mystery as the DOE appears to have no intent to engage the states and citizens in any meaningful way. Giving the DOE authority to unilaterally reclassify its HLW to low-level waste will mean unsafe disposal on DOE sites at Savannah River Site, Hanford and Idaho National Laboratory. Calcine seismic safety issues and calcine flooding issues remain inadequately addressed and inadequately explained to the CAB. The Big Lost River flow onto the INL site at the southwestern corner and then flows northeast to INTEC when the calcine bin sets are located. [13] The Big Lost River sinks are located at the northern portion of the INL.
- The U.S. Geological Survey gave a brief presentation about a limited look at INL radiological and chemical contamination in the Snake River Plain aquifer. **Emphasis was placed on interbed layers below the Radioactive Waste Management Complex burial ground or subsurface disposal area preventing contaminant migration — but there was no explanation of how the burial ground contaminants have reached the aquifer. For example, carbon tetrachloride levels in the aquifer below the burial ground exceed federal drinking water standards despite years of vapor extraction and waste exhumation of waste laden with the chemical.** The multilevel deep well placed down-gradient of highly contaminated Test Area North (and north of the ATR Complex) remains completely unsampled, perhaps so as to not disturb propaganda about the efficacy of sediment interbeds under Test Area North. Other multi-level deep well monitoring debacles were not mentioned. Not clarified during the presentation is the fact that the radioactive half-life of iodine-129 is 17 million years. When I-129 or other contaminant levels decrease in a well, that is because the contaminant has migrated in the aquifer downgradient toward Twin Falls and Thousand Springs.
- The CAB continues to struggle with basic understanding of fundamental issues involving HLW, waste disposal, waste storage safety, history of DOE's shenanigans, and radiation health impacts — all while being pressured to agree with whatever the Department of Energy is promoting. Kudos to those CAB members who are struggling to understand many difficult issues and are not inclined to ill-informed knee-jerk reactions nor to automatic acceptance of all of the Department of Energy's propaganda.

[13] Calcined Solids Storage Comment Submittal (Docket No. 10W-1604), by Chuck Broscious and Tami Thatcher, July 11, 2016. http://www.environmental-defense-institute.org/publications/EDICalcineComments.pdf

Idaho Cleanup Project Citizens Advisory Board Not Told How Much Radioactive Waste Will Remain Buried at INL

The Idaho Cleanup Project Citizens Advisory Board and the public continue to be misinformed about how much radioactive waste, including transuranic waste, will remain buried at the Idaho National Laboratory's Radioactive Waste Management Complex Subsurface Disposal Area, formerly known as the "burial ground."

Despite misleading and inaccurate press releases and reporting implying that "all the waste" buried or stored at the Idaho National Laboratory is being removed, [14] none of the non-transuranic buried radioactive waste is being removed and only a small fraction of the buried transuranic waste will be exhumed and removed from Idaho.

In 2008 the Department of Energy, Idaho Department of Environmental Quality, and Environmental Protection Agency signed on to a plan to exhume a limited amount of buried waste at the Radioactive Waste Management Complex. Despite the "all means all" ruling regarding the 1995 Idaho Settlement Agreement to remove all transuranic waste at the Idaho National Laboratory, the tri-agency agreement specifies retrieval of at least 5.69 acres "determined to contain the highest density of "targeted waste" and shipment of at least 7,485 cubic meters of retrieved and packaged targeted waste out of the state of Idaho.

DOE argued against digging up meaningful amounts of transuranic and other long-lived radioactive waste at the Radioactive Waste Management Complex. Only the most egregious chemically laden waste is being removed. [15] [16] Of the 5.69 acres to be exhumed of the 35 burial ground acres of the burial ground, much of the exhumed waste is returned for burial.

Radioactive waste buried at RWMC has included examined spent nuclear fuel, activated metals, and as well as transuranic waste that should have no place in a shallow land burial. The "targeted waste" in the subsurface disposal area focused on the most chemically contaminated waste from the Rocky Flats nuclear weapons plant in Colorado because of already extensive

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[14] Nathan Brown, *The Idaho Falls Post Register*, "Fluor says just .69 acres of waste left at desert complex," April 23, 2019.

[15] 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 and 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. Available at INL's DOE-ID Public Reading room electronic collection. (Newly released because of Environmental Defense Institute's Freedom of Information Act request.) See https://www.inl.gov/about-inl/general-information/doe-public-reading-room/

[16] See the CERCLA administrative record at www.ar.icp.doe.gov (previously at ar.inel.gov) and see also Parsons, Alva M., James M. McCarthy, M. Kay Adler Flitton, Renee Y. Bowser, and Dale A. Cresap, Annual Performance Assessment and Composite Analysis Review for the Active Low-Level Waste Disposal Facility at the RWMC FY 2013, RPT-1267, 2014, Idaho Cleanup Project. And see Prepared for Department of Energy Idaho Operations Office, Phase 1 Interim Remedial Action Report for Operable Unit 7-13/14 Targeted Waste Retrievals, DOE/ID-11396, Revision 3, October 2014 https://ar.inl.gov/images/pdf/201411/2014110300960BRU.pdf

contamination of the Snake River Plain aquifer due to the chemical contamination, mainly carbon tetrachloride. [17] [18] Even for areas exhumed, much of the radioactive material will remain buried.

The targeted waste includes:

- 741 Sludge: Fairly homogeneous solid of salt precipitate containing plutonium and americium oxides and organic constituents
- 742 Sludge: Fairly homogeneous solid of salt precipitate containing plutonium and americium oxides, metal oxides, and organic constituents
- 743 Sludge: Past or grease-like solidified organic liquid containing hazardous solvents and calcium silicate
- Graphite Waste: Broken graphite mold chunks and poly bottles of fine particles (e.g., graphite scarfings) containing residual plutonium
- Filters and pre-filters: Discarded high-efficiency particulate air (HEPA) filters contaminated with transuranic and uranium radionuclides
- Uranium Roaster oxide: Depleted uranium historically roasted at high temperatures, primarily in the form of uranium oxide, with some uranium metal possible
- Other waste streams mutually agreed by the three agencies to routinely be recognizable as transuranic waste.

Series 741 and 742 Sludge are generally the same in appearance and packaging. The identification of materials is visual. It is not possible to know how much waste was actually buried nor how many curies are actually exhumed. **But the Department of Energy's Performance Assessment and Composite Analysis, the analyses estimating the groundwater contamination in the future for thousands of years from the migration of contaminants in the buried waste, assumes that most of the transuranic waste and all of the non-transuranic waste is remaining buried at the burial ground, able to leach into the aquifer over the millennia that the waste is toxic.** [19]

[17] North Wind Inc. for U.S. Department of Energy, Environmental Management, "Historical Background Report for Rocky Flats Plant Waste Shipped to the INEEL and Buried in the SDA from 1954 to 1971," ICP/EXT-04-00248, Revision 1, February 2005. https://ar.icp.doe.gov/images/pdf/200504/2005040400022KAH.pdf

[18] See the July 2017 EDI newsletter for a timeline for the burial ground at the Radioactive Waste Management Complex and other cleanup information at http://www.environmental-defense-institute.org/publications/News.17.July.pdf

[19] 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 and 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. Available at INL's DOE-ID Public Reading room electronic collection. (Newly released because of Environmental Defense Institute's Freedom of Information Act request.) See https://www.inl.gov/about-inl/general-information/doe-public-reading-room/

For example, 215,000 curies of americium-241 at the RWMC will remain buried at the RWMC burial ground. It would require 6 Snake River Plain aquifers to dilute the americium-241 to drinking water standards. [20]

For disposal of spent nuclear fuel and high-level waste proposed at Yucca Mountain, the courts decided that for Yucca Mountain, analysis to an arbitrary 10,000 years was unacceptable—if peak radiation ingestion doses were afterward. Yet, RWMC cleanup at the INL is based on models that minimize the release for the first 10,000 years. Then the Department of Energy failed to mention the rapidly escalating migration of radionuclides and radiation ingestion doses after 10,000 years from the migration of contaminants into the aquifer from the burial ground.

The DOE kept its analysis of peak doses at RWMC out of public view: 100 mrem/yr for hundreds of thousands of years unless the soil cap is maintained perfectly. That's assuming no floods and geologic stability over millennia: in other words, a scientifically indefensible analysis. [21]

They say other burial grounds at INL will have caps, but leave out that only RWMC **relies** on soil cap performance to slow the migration of radionuclides headed for Thousand Springs for millennia, that today's aquifer monitoring does not portray. [22]

The DOE continues to bury radioactive waste over our Snake River Plain aquifer. [23] The DOE hasn't decided how much they will ultimately bury at the replacement for the RWMC, the Remote Handled Low-Level Waste disposal facility at the Idaho National Laboratory. The RHLLW facility allows disposal of Greater-Than-Class-C long-lived radionuclides that are expected to migrate into the Snake River Plain aquifer. The concentrations of nickel-59, nickel-

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[20] See ar.icp.doe.gov (formerly ar.inel.gov) or DOE-ID Public Reading room 2013 "RPT-1267" which states **2.15E5** curies of Am-241 are buried at RWMC. Snake River Plain aquifer volume is estimated at 2.44E15 liters (see www.ieer.org). The maximum contaminant level assumed 15 picoCuries/liter for alpha emitters.

[21] Idaho National Laboratory, "Explanation of Significant Differences Between Models Used to Assess Groundwater Impacts for the Disposal of Greater-Than-Class C Low-Level Radioactive Waste and Greater-Than-Class-C-Like Waste Environmental Impact Statement (DOE/EIS-0375D) and the Environmental Assessment for the INL Remote-Handled Low-Level Waste Disposal Project (INL/EXT-10-19168)," INL/EXT-11-23102, August 2011. http://www.inl.gov/technicalpublications/documents/5144355.pdf and a report prepared for the US Department of Energy, DOE Idaho Operations Office, "Preliminary Review of Models, Assumptions, and Key Data Used in Performance Assessments and Composite Analysis at the Idaho National Laboratory," INL/EXT-09-16417, July 2009. See p. 11, Tables 3 and 4 for sorption coefficients.

[22] See recently asked questions for April 8, 2015 Idaho National Laboratory Environmental Management Citizens Advisory Board, http://inlcab.energy.gov/pages/recently-asked-questions.php

[23] 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 and see EDI's report "Unwarranted Confidence in DOE's Low-Level Waste Facility Performance Assessment – The INL Replacement Facility Will Contaminate Our Aquifer for Thousands of Years" at http://www.environmental-defense-institute.org/publications/rhllwFINALwithFigs4.pdf

63 and niobium-94 are expected to exceed Class C and could not be disposed of at a commercial low-level waste disposal facility.

For the RWMC burial ground and for the RHLLW facility, the computations to provide the Performance Assessment for the rate at which the radionuclides will migrate into the aquifer are based on unsupported assumptions regarding optimistic selection of properties to slow the estimated rate of migration, assumption of uniform mixing in the aquifer while ignoring the known presence of "fast paths," the presumed lack of flooding, and stable geology for the need million and more years. The DOE hopes to increase the amounts of radionuclides buried over the aquifer without so much as even the pretense of a soil cap to slow the migration of radionuclides into the aquifer.

US Ecology Idaho Update on Last November's Explosion

Here's what the Idaho Department of Environmental Quality called the containment building for the US Ecology Idaho Grandview facility that the state authorized to receive, treat and store non-hazardous wastes, RCRA, PCB and "low radiation exempted" wastes:

This picture was taken after the explosion last November 17, 2018 that involved 7000 pounds of magnesium **during treatment of a waste they are authorized to receive**. Neither the Idaho

DEQ nor US Ecology have released information about what this waste stream was that caused the explosion.

Three workers from the facility were injured in the explosion and one man was killed. The explosion caused damage to surrounding buildings, which may have contained hazardous waste. There was an initial fire resulting from the explosion that burned out by the evening of November 17, 2018.

Video footage of the explosion taken several miles from the explosion has been posted by 7KTVB news and shows the impressive height of the explosion, perhaps hundreds of feet in the air. [24] Magnesium oxide was used as an additive in the mixing bins in the building that exploded. Two of the waste mixing bins are 17 ft by 60 ft and are 8 ft deep.

The hazardous waste permit for the US Ecology Idaho (site B) facility near Grand View, Idaho discusses the use of "lime" to mix with hazardous wastes. In its permit, lime is defined as "containing oxides and/or hydroxides of calcium and/or magnesium." [25]

The Idaho DEQ may have had to issue an emergency permit for the Rail Transfer Facility, which only has a 10-day storage limit, and the US Ecology Idaho Grandview (Site B) facility, which has a 1-year storage limit, as USEI works through the response.

Idaho DEQ has not released any results of radiological monitoring of the facility conducted after the explosion.

After the explosion, the Idaho DEQ requested a list of chemicals that the US Ecology had in the buildings. Perhaps it would have been helpful for Idaho DEQ as well as emergency responders to know what US Ecology had in the buildings?

The hazardous waste permit for the facility requires conducting chemical compatibility analyses. [26] But the permit doesn't require much in the way of sampling of the materials to verify waste constituents. Nor does the permit have any documented chemical compatibility analyses, not even for the mixing bins used to "neutralize" some materials. Apparently, it is just assumed

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[24] Video footage caught by passerby of the explosion at the Grand View US Ecology Idaho facility, posted on 7KTVB.com news, November 2018. https://www.ktvb.com/video/news/local/grand-view-man-killed-in-explosion-at-us-ecology-site/277-8336847

[25] US Ecology Idaho Inc. Site B facility located in Owyhee county near Grand View, Idaho (USEI), EPA Facility Identification Number: IDD073114654. The permit describes four mixing bins in the building that exploded, each having 120 cubic yard capacity. http://www.deq.idaho.gov/media/1117319/us-ecology-site-b-grand-view-permit.pdf The RCRA mixing bins are each 17 ft by 60 ft and are 8 ft deep. http://www.deq.idaho.gov/media/60178905/us-ecology-site-b-grand-view-att14a.pdf The permit's waste analysis plan uses the term lime several times. In one instance, lime is defined as follows: "lime (i.e., containing oxides and /or hydroxides of calcium and/or magnesium [ )]." http://www.deq.idaho.gov/media/60178892/us-ecology-site-b-grand-view-att2.pdf

[26] The US Ecology Idaho facility at Grand View, permit attachment 2 describes the requirement to conduct chemical compatibility of the waste streams. It generally uses EPA-600/2-80-076 (see https://www.epa.gov/sites/production/files/2016-03/documents/compat-haz-waste.pdf) But the permit has no specific evaluations discussing chemical compatibility and the mixing bins that frequently used magnesium oxide to mix with waste. http://www.deq.idaho.gov/media/60178892/us-ecology-site-b-grand-view-att2.pdf

that chemical compatibility analyses are conducted — all without documentation or DEQ review apparently.

Radiological materials were on the site at Pad-4 and Pad-5, and it has been stated that there was no damage at that location. [27] However, in the past, radiological materials have been treated inside the building that exploded. If no radiological materials were released, why all the secrecy about the waste that caused the explosion and why the refusal to release radiological monitoring data?

Plutonium-238 More Difficult to Control and Contain than Plutonium-239 — Here's Why

A report by Oak Ridge National Laboratories explains the reasons why plutonium-238 is more difficult to control and contain than plutonium-239. [28] A phenomenon called **alpha recoil** causes particles to move as the result of radioactive decay. This movement can affect the ability to retain particles in HEPA filters, as well the control of radioactive particles in radioactive contamination. The higher the specific activity of the radioisotope, the more often the particle decays. The more often it decays, the more movement of the particles is observed. The size of the particles can also depend on the processing that the material has been had.

Plutonium-238 has a much higher specific activity than plutonium-239. Experience at the Savannah River Site has documented the greater difficulty in controlling Pu-238 contamination, particularly when processing had created small diameter particles even though Pu-239 is handled more often.

Similarly, curium-244 and californium-252 each have high specific activities and are difficult to control. At the Oak Ridge National Laboratory, Cm-244 and Cf-252 are processed in the liquid phase as much as practical because powders are difficult to control. Curium and californium were in waste brought to Idaho from the Rocky Plants weapons production plant. [29]

"Fragmentation" of high-specific-activity alpha emitters is also a concern because smaller particles can be more easily taken up by the human body. Past lung studies found that $^{238}PuO_2$ which is more short-lived and more prone to fragmentation, dissolves 200 times faster than $^{239}PuO_2$.

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[27] Idaho State Communications Center Hazmat, H-2018-00222, 11/17/2018 11:05 through 01/04/2019, 18 pages. See Environmental Protection Agency Freedom of Information document R10-100140488 and others at https://foiaonline.gov/foiaonline/action/public/submissionDetails?trackingNumber=EPA-R10-2019-003499&type=request

[28] A. S. Icenhour, Oak Ridge National Laboratory, Nuclear Science and Technology Division, "Transport of Radioactive Material by Alpha Recoil," ORNL/TM-2005/22, May 2005. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.544.9833&rep=rep1&type=pdf

[29] North Wind Inc. for U.S. Department of Energy, Environmental Management, "Historical Background Report for Rocky Flats Plant Waste Shipped to the INEEL and Buried in the SDA from 1954 to 1971," ICP/EXT-04-00248, Revision 1, February 2005. https://ar.icp.doe.gov/images/pdf/200504/2005040400022KAH.pdf

"Resuspension" is the movement of radioactive particles with air currents and their transport to another location. Resuspension has been studied indoors, with dry Pu-238 particles tending to not to stick to surfaces, and outdoors, with Pu-238 particles sometimes readily traveling hundreds of feet.

High-specific activity alpha emitters can also cause failures of 35 mil thick rubber gloves, even in a matter of days, the reported noted.

Table 2 provides a comparison of long-lived plutonium-239 to higher specific activity transuranics plutonium-238, curium-244 and californium-252. Note that the each of these radionuclides decay in a long decay series before non-radioactive lead remains.

Table 2. Comparison of plutonium-239 characteristics with plutonium-238, curium-244 and californium-252.

Characteristic	Plutonium-239	Plutonium-238	Curium-244	Californium-252
Specific activity	0.063 curie/g	**17 curie/g**	**82 curie/g**	**540 Ci/g**
Half life	24,000 year	**88 year**	**18 year**	**2.6 year**
Primary decay mode and energy	5.1 MeV	5.5 MeV	5.8 MeV	5.9 MeV
Beta decay energy	0.067 MeV	0.011 MeV	0.086 MeV	0.0056 MeV
Gamma, energy	<0.001 MeV	0.0018 MeV	0.0017 MeV	0.0012 MeV

Table notes: Curie/g is curie/gram; MeV is Million electron volts.

Report INL/EXT-15-34927 listed radionuclides important in terms of radiological dose based on the 2007 to 2013 National Emission Standards for Hazardous Air Pollutants (NESHAP) reports. [30] The radionuclides in Idaho National Laboratory estimated air emissions for 2007 to 2013 included almost 20 percent of the radiological dose from plutonium-239/240, 8 percent of the dose from americium-241, 1.5 percent of the dose from plutonium-238, and less than 1 percent each of the dose from curium-244 and californium-252. Most of the radiological dose from estimated INL air emissions for 2007 to 2013 not already listed in this paragraph are due to tritium, cesium-139, strontium-90, argon-41 and iodine-129, according to INL/EXT-15-34927.

Higher actinides such as californium, curium, americium and neptunium may be produced using target material in nuclear reactors in order to produce weapons related materials or to

[30] T. J. Haney, Battelle Energy Alliance for the Idaho National Laboratory, *Data Quality Objectives Summary Report Supporting Radiological Air Surveillance Monitoring for the INL Site*, INL/EXT-15-34927, May 2015. https://inldigitallibrary.inl.gov/sites/sti/sti/6720815.pdf

produce a heat source for radiothermal generators such as plutonium-238 which is used as a power supply in spacecraft. [31] These materials have been disposed of to an open-air evaporation pond at the INL's ATR Complex. These materials have not necessarily been included in required federal reporting under the National Emissions Standards (NESHAPs) because they are not monitored but only estimated.

Plutonium-238 is processed at the Materials and Fuels Complex at the INL for use as a power source for space applications. While plutonium-238 as well as plutonium-239 are generated in reactor spent nuclear fuel and may be released by spent fuel reprocessing, whether chemical separations or pyroprocessing. Concentrated plutonium from special irradiated targets can be released as it is separated, stored, disposed of or undergoes machining processes.

Plutonium, americium, uranium and other transuranic radionuclides from nuclear weapons production and research has been disposed of at the INL. Contamination of Idaho soil and air has occurred from historical and ongoing waste operations. The exhumation, sorting and packaging of the chemically laden "targeted" waste exhumed from the burial ground has generated releases to the air. In addition to buried waste, some Rocky Flats waste was stored above ground at the Advanced Mixed Waste Treatment Project (AMWTP). Repackaging this waste prior to shipment to the Waste Isolation Pilot Plant (WIPP) in New Mexico has also resulted in airborne contamination with plutonium and other radionuclides.

Analysis of air filter samples at or near the INL has periodically detected elevated levels of plutonium-238, plutonium-239 and americium-241 in our Idaho air. The prominence of the plutonium and americium exceeds what would be expected from historical nuclear weapons testing fallout or reactor fuel melt releases from the INL. The frequent occurrence of higher amounts of plutonium-238 than plutonium-239 in offsite air filters indicates special processes at the INL are releasing excessive levels of plutonium-238, at least sporadically.

Actinides are created by neutron capture in a nuclear reactor and these include the actinides neptunium, plutonium, americium, curium and californium.

Plutonium-239 decays to uranium-235 and decays through the uranium-235 decay series. See this decay series and others in the Environmental Defense Institute February 2018 newsletter. Uranium-238 decays to uranium-234, and plutonium-238 also decays to uranium-234 and decays through the uranium-238 decay series. Curium-244 and california-252 decay to thorium-232 and decay through the thorium-232 decay series. Plutonium extracted from spent fuel or from special irradiated targets always contains a variety of plutonium isotopes that cannot be separated out. Material that is largely plutonium-239 will contain other plutonium isotopes such as plutonium-241. The plutonium-241 decays causing the buildup of americium-241 over time.

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

The environmental monitoring of airborne radioactivity that is conducted at or near the INL tends to ignore peaks and appears to be missing weeks of data in graphs charting alpha and gamma airborne radiation levels. This can be observed for various years, but is particularly obvious in 2006. [32]

Particulate matter in filters for 2006 provide instances of elevated levels of radionuclides such as plutonium-239, plutonium-238 and americium-241 in the filters only sometimes occurring with cesium-137 and strontium-90. [33] A high statistical bar allows denial that a "detection" of the radionuclide occurred. Furthermore, the Idaho Department of Environmental Quality is removing its historical air emissions monitoring reports from its website when the data are a few years old.

Elevated levels of gross alpha contamination found in public drinking water that are not explained by naturally occurring levels of uranium and thorium are typically not analyzed to explain what radionuclides are causing the elevated gross alpha radiation in the water. [34] [35]

Natural levels of uranium and thorium levels in ground water in Idaho should be 3 picocuries/liter (pCi/L) or less. But levels of gross alpha in Idaho drinking water often exceed this, and may exceed 30 pCi/L intermittently. **The buildup of long-lived radionuclides in Idaho's air, water and soil includes transuranic radionuclides such as plutonium and americium and it continues today.**

Articles by Tami Thatcher for May 2019.

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

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[34] Environmental Defense Institute newsletter for December 2017 "Where to Find Out More About Your Drinking Water." http://www.environmental-defense-institute.org/publications/News.17.Dec.pdf

[35] Environmental Defense Institute newsletter for February 2018 that contains several articles about drinking water: "What's Up with the Radionuclides in Drinking Water Around Boise, Idaho?" "Radionuclides in Drinking Water in Ammon, Idaho," "Understanding the Radionuclide MCLs in Drinking Water in Idaho," and "Understanding the Man-Made Radionuclides in Drinking Water in Idaho (with helpful decay chain information for uranium-238, thorium-232, uranium-235 and uranium-233 and the man-made actinides that can feed these decay series)" http://www.environmental-defense-institute.org/publications/News.18.Feb.pdf