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Old, Unsafe Nuclear Weapons Pit Production at Los Alamos, Now to Operate 24/7, As Pit Costs Balloon

The National Nuclear Security Administration (NNSA) knew it couldn't meet its 80 pit per year production goal by 2030 even though it was mandated by Congress. And they know that round-the-clock operations at the Los Alamos National Laboratory's main plutonium facility (PF-4) wouldn't produce 80 pits per year either. But LANL hopes to produce 30 pits per year by ramping up to 24/7 operations.

The ramp-up to 24-hours-a-day, seven-days-a-week operations at LANL's plutonium facility was documented in a Defense Nuclear Facilities Safety Board memorandum. [1] **They expect night shift work to ramp up in tempo and complexity**. The need to supervise the new additional staffing as well as the difficulty of performing work safety 24/7 will create unsafe conditions at a facility not known for its attention to safety in the first place.

It was LANL that loaded ***many*** transuranic waste drums with known-to-be-prohibited organic kitty litter with nitrate wastes, one of which exploded in the Waste Isolation Pilot (WIPP) underground salt mine for defense waste disposal in 2014.

The Los Alamos Study Group obtained via Freedom of Information Act (FOIA) an NNSA May 2021 document *Assessment of the Pit Production at Los Alamos National Laboratory Plan – Report to Congress*. It stated that "The U.S. had not manufactured a plutonium pit since 2012 and has not had the ability to manufacture more than 10 pits per year (ppy), since the closure of the Department of Energy's Rocky Flats Plant in 1992. Currently, the only U.S. facility capable of producing war reserve pits is the Technical Area-55 (TA-55) Plutonium Facility-4 (PF-4) at the Los Alamos National Laboratory (LANL), in Los Alamos, New Mexico. PF-4 is a Hazard Category (HC)-2/Security Category (CAT)-I facility."

The pit production plan also noted that pit production at LANL is highly dependent on the removal of nuclear waste, namely, of transuranic waste drums stored at LANL that need to be shipped offsite to the Waste Isolation Pilot Plant (WIPP), also in New Mexico.

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[1] Defense Nuclear Facilities Safety Board, Los Alamos Activity Report for Week Ending February 4, 2022, Memorandum dated February 4, 2022. "This week, Triad management commenced operations in the facility 24 hours a day, seven days a week. In the near-term, night shift activity will be similar type and tempo as to what was previously performed on the backshift. Longer term, they expect night shift activity to significantly ramp-up in tempo and complexity."

The Los Alamos Study Group, founded in 1989 by Greg Mello and others, has a website that documents the cost increases and other problems associated with nuclear weapons pit production. [2]

In addition to weapons pit production, the Los Alamos Study Group also noted that a December 3, 2021 Defense Nuclear Facilities Safety Board Memorandum stating that the NNSA was allowing an increase to the material-at-risk from heat source plutonium [i.e., plutonium-238] that would allow the mitigated public dose from a post-seismic fire accident to increase from 25 rem **to the range of 83 to 378 rem** when the material is not stored in credited containers. [3] It is known that the LD-50/60 for whole body radiation is about 400 rem, meaning that 50 percent of adults exposed to 400 rem would die within 60 days. What many people may not know is that the release of transuranic material to produce these doses would mean "forever" extensive contamination many miles of land. By the way, if you needed any more evidence, this proves these idiots are out of control.

HALEU Fuel for the TerraPower's Proposed Sodium-Cooled Natrium Nuclear Plants Could be Impacted by Ban on Russian Imports of Low-Enriched Uranium

There are calls for banning the import of low-enriched uranium from Russia, in response to Russia's attack on Ukraine. According to a WyoFile non-profit news organization published in The Idaho Falls Post Register [4] the U.S. has been supplied approximately 16 percent of its low-enriched uranium since 2020.

A ban on Russian uranium imports could result in spiking nuclear fuel prices. Kazakhstan and Uzbekistan together also provide 30 percent of the imports to the U.S.

Domestic uranium production in western states of Arizona, Colorado, New Mexico, Utah and Wyoming, is highly environmentally polluting, had diminished over the past decade. Uranium mining and other processes produce mill tailings and other radioactive pollution that threaten rivers, other water supplies and soil and airborne contamination.

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[2] Los Alamos Study Group at https://www.lasg.org/sites/lanl.htm and see NNSA and other federal planning budgeting request and related articles at https://www.lasg.org/budget/NNSA_Planning_Budgeting.html

[3] Defense Nuclear Facilities Safety Board, Los Alamos Activity Report for Week Ending December 3, 2021, Memorandum dated December 3, 2021. "The addendum would allow an increase to material-at-risk limits as this activity will exceed the current first floor and glovebox limits until repackaged in credited containers. The mitigated public dose due to the bounding post-seismic fire accident is estimated to be a range from 83 to 378 rem because there is substantial uncertainty regarding the leak path factor that can be appropriately applied to the scenario. The increased doses are applicable during the time when the new material is not in credited containers. As this exceeds the DOE evaluation guideline of 25 rem to the public, Triad is requesting that NNSA accept the risk involved with performing this mission."

[4] Dustin Bleizeffer, *WyoFile, The Idaho Falls Post Register*, "TerraPower boost nuclear fuel effort amid calls for import ban," March 23, 2022.

After uranium is mined, it must be extracted from the ore. Less than 1 percent of the ore contains uranium and so the mill tailings left behind are extensive in volume that have nearly 80 percent of the original radioactivity that is no longer safely bound up in the rock. And instead of being below ground, it may be piled in heaps above ground.

Mined uranium ore is milled, usually treated by grinding and chemical leaching to extract the natural uranium called "yellowcake" or U_3O_8. Mill tailings concentrate radioactive material, leaving it to contaminate water and land. Adverse health effects such as cancer and increased birth defects result from mining and milling wastes that are not even called "low level" waste. The half-lives are thousands of years so the radioactive toxicity of the waste isn't going away.

Bankrupt companies leave the mines and mill tailings waste behind even if the U.S. Nuclear Regulatory Commission licensed it and the new owner becomes the Department of Energy, funded by U.S. taxpayers. Remediation is an optimistic term applied to what will never return damaged landscape to a healthy environment. For example, the movement of uranium mill tailings away from the Colorado River near Moab, Utah required the Department of Energy to take ownership of the site and a nearly billion-dollar effort to move the toxic tailings. [5]

"Mining and milling operations have disproportionately affected indigenous populations around the globe. For example, in the U.S. nearly one-third of all mill tailings from abandoned mill operations are on the lands of the Navajo nation alone." [6]

There are countless polluted uranium fuel industry sites around the U.S. And when those sites are cleaned up, their waste is often brought by truck or by rail car through Pocatello to Idaho's underregulated US Ecology's Grand View disposal facility.

TerraPower is working toward having domestic capacity for commercial scale nuclear fuels such as high-assay low-enriched uranium (HALEU) fuels. HALEU fuel is just under 20 percent enriched in uranium-235, whereas typical commercial nuclear reactors built in the U.S. in the 1970s used about 3 percent enriched fuels. Higher burnup fuels in the U.S. have edged up to around 5 percent enrichment. The higher enriched fuels can be operated longer in a reactor and also create more fission products and more plutonium and americium in their spent fuel.

The Idaho National Laboratory has created HALEU feedstock materials, with high airborne releases due to its production at the Materials and Fuels Complex, but it does not fabricate nuclear fuels.

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[5] US Department of Energy, Factsheet "Overview of Moab [Uranium Mill Tailings Remedial Action] UMTRA Project," 2017. http://www.gjem.energy.gov/moab/documents/factsheets/20170316OVERVIEW.pdf See also *Citizens Monitoring and Technical Assessment Fund,* "A Short History of the Moab Project and The White Mesa Mill Alternative," http://www2.clarku.edu/mtafund/prodlib/dine/round5/Short_History.pdf

[6] Arjun Makhijani and Scott Sleska, *The Nuclear Power Deception – U.S. Nuclear Mythology from Electricity "Too Cheap to meter" to "Inherently Safe" Reactors*, 1999, by the Institute for Energy and Environmental Research, The Apex Press, ISBN 0-945257-75-9. See p. 219 taken from Gilles, et al. 1990.

Battelle Energy's Creative Approach to Internal Dose Estimation

When a serious plutonium and americium inhalation event occurred affecting 16 workers at the Idaho National Laboratory on November 8, 2011, it would take many months before the assessment of radiation doses from inhaling plutonium and americium would be completed.

But the months of time taken for completing the radiation dose assessments may not correlate with the accuracy of the dose assessment. In fact, of the range of possible radiation doses from the November 8, 2011 accident to one worker, Battelle Energy Alliance settled on a radiation dose **far too low** to be consistent with the evidence.

The various methods of estimating the intake of radioactive material into the body can indicate what the intake might be. However, despite decades of research with regard to the study of these materials and how the materials are distributed in the body, there are many variables affecting the accuracy of the intake estimates. The estimated intake is used to estimate the radiation dose. **And by the modeling assumptions made during radiation dose assessment, a dosimetrist can return almost anything, from a dose of almost nil (less than 100 millirem) to a dose over one thousand times higher, over 100 rem.**

When the company employing the dosimetrist wants the result to be almost nil, guess what the dosimetrist will arrive at.

To try to estimate the radiation dose from inhalation doses of plutonium and americium, there are various indicators to examine. These include Constant Air Monitor filters and alarms, area contamination swipes, and personnel monitoring of clothing and skin. When an intake is suspected based on these, nasal swabs may be taken but must be taken within 1 to 2 hours of the suspected inhalation. It is sometimes assumed that 5 percent of the radioactive material inhaled, called the "intake" might be in nasal swab activity (from both nostrils added together).

In a wound entry of a soluble form of plutonium, americium or higher actinide such as curium, chelation intravenous treatment needs to be applied as soon as possible, probably within 2 hours of the intake because of how rapidly plutonium or americium in the blood stream are absorbed into the body. For a suspected inhalation, particularly of insoluble forms of plutonium or americium, chelation may be far less effective. While many studies of chelation effectiveness have been conducted, the wide variations due to the solubility, particle size and chemical form of the radionuclides inhaled, the amount inhaled and the timing of chelation have produced widely varying assessment of chelation effectiveness. The radionuclides can be difficult to detect in bioassay samples, such as urine. The review of the scientific literature since 1979 for chelating agents such as calcium diethylenetriaminepentaacetic acid (Ca-DTPA) was summarized in a 2019 report issued by Los Alamos National Laboratory. [7] This report, which did not discuss any aspect of the differences in the solubility or particle size of the inhaled material, found a wide range of chelation *enhancement factor* estimates, from 0.7 to 120. The chelation *enhancement*

[7] Sara de Souza Zanotta Dumit, et al., Los Alamos National Laboratory, *Chelation Modeling*, LA-UR-19-21557, 2019. http://permalink.lanl.gov/object/view?what=info:lanl-repo/lareport/LA-UR-19-21557

factor is the ratio of the urinary excretion on the day of chelation to the urinary excretion that would be expected without chelation. In other words, for a direct intake of plutonium or americium into the blood stream, chelation is certainly needed. But with the inhalation of plutonium or americium, the effectiveness of chelation is anyone's guess.

After a suspected inhalation, lung counting is conducted at Department of Energy facilities. And because americium-241 is usually present along with plutonium, and because the Am-241 is more easily detected, the detection of Am-241 by a lung count is typically used to estimate the amount of plutonium also present, based on known composition of the material inhaled. And urine and fecal bioassay samples are collected and analyzed for the radioactive materials.

In order for a radiation dose assessment to be conducted, the material composition must also be determined as well as the solubility of the material inhaled. The radionuclides collected on nasal swabs may be analyzed to determine the radionuclides inhaled.

I found that Battelle Energy Alliance took a very creative, how-low-can-you-go approach for estimating the radiation dose from the intakes of plutonium and americium from the November 8, 2011 accident at the ZPPR facility, [8] see Table 1.

Table 1. Plutonium and americium intake assessment methods and BEA approach.

Method	What Should Be Done, and As-Found Status	What BEA Did and What BEA Reported
Area contamination swipes	5.5 million disintegrations per minute (dpm) found.	Use 791 DAC for Pu-239 from CAM reading, CAM located 15 ft from workers. Derive an estimated intake of 1100 dpm based this.
Area Constant Air Monitor	Greater than 4657 derived air concentration (DAC) units, 15-ft away from workers.	Use 791 DAC for Pu-239 from CAM reading, CAM located 15 ft from workers. Derive an estimated intake of 1100 dpm based this.
Clothing and skin surveys	Very high dpm on clothing found.	Survey skin while damp, yet no showers available for thorough washing.
Nasal swabs exceeding 10 dpm	Nasal swabs taken and recorded in logbook, 4000 dpm.	Report to REAC/TS maximum of 150 dpm total alpha radiation for nasal swab. A value of 289 dpm acknowledged by the DOE Accident Investigation, but this is only Pu-239, not total alpha. Origin of the 150 dpm

[8] U.S. Department of Energy Office of Health, Safety and Security Accident Investigation Report, *Plutonium Contamination in the Zero Power Physics Reactor Facility at the Idaho National Laboratory, November 8, 2011*, January 2012.

Method	What Should Be Done, and As-Found Status	What BEA Did and What BEA Reported
		nasal swab basis is unknown and incorrectly underestimates the result for a single nasal swab, but is used by BEA medical as though reliable information. Logbook recording initial nasal swab information is destroyed.
Based on above, determine that chelation treatment is needed	Chelation needed within 2 hours of intake. Based on Oak Ridge REAC/TS recommendation, BEA prepares to provide chelation to about 16 workers. BEA provides chelation to 4 workers about 4 hours after inhalation.	Later, lack any knowledge of why chelation therapy was needed. Destroy logbooks of the information indicating very serious inhalation event had occurred. Also ignore contraindication of high uranium composition of the ZPPR plates despite potential Pu and Am chelation.
Vomiting	Workers are vomiting in trash cans and later, at home. Vomit should be collected for bioassay. [a]	Do not collect vomit samples and no matter what workers say, state in medical dictations that there was no vomiting.
Obtain complete blood counts (CBCs) from workers.	A proper response would be to assess any irregularities, such as decreased lymphocyte or monocyte counts. These indicate hemopoietic syndrome, expected because of the high radiosensitivity of bone marrow and the bone-seeking characteristics of americium and plutonium.	Take blood for a Complete Blood Count (CBC) once, then discontinue blood draws. Ignore clear signs from the single blood draw that within 4 hours of the accident, significant drop in lymphocyte, monocyte, etc. counts had already occurred.
Conduct lung counts using high-purity germanium detectors	Americium-241 is typically the focus of lung counts because it is easier to detect than plutonium-239. A proper response would be to provide all lung counts, including all positive, greater than Decision Level lung counts, for upper bound dose estimate by Oak Ridge.	Discard any lung count result that would result in upper bound dose estimates exceeding annual dose allowable criteria, no matter that no reason for ignoring the lung count has been found. Manipulate lung count results and fail to explain numerous irregularities in many lung counts.

Method	What Should Be Done, and As-Found Status	What BEA Did and What BEA Reported
Urine bioassay	Conduct urine bioassay.	Fail to note time of sample collection. Destroy first 24-hour americium-241 urine samples. Fail to address apparent higher solubility of Am-241 because americium-241 is twice as high as the plutonium-239 in the urine samples. Plate composition indicates Am-241 activity times 1.5 should equal the plutonium-239 activity.
Fecal bioassay	Conduct fecal bioassay. Understand that the fecal sample collected in the first 24 hours will include radioactivity from posterior nasal passage and pharynx and would be expected to be the highest sample result. [b]	Fail to note time of sample collection. State that the high radioactivity of the first fecal sample in the first 24 hours is "unexpected" and discount this sample accordingly. Use the low-balled fecal modeling to constrain the results deemed acceptable from the urine analysis. Ignore low fecal sample volume. Ignore vomit excretion.
Fecal bioassay, long term	A proper response would be to inform worker of positive bioassay from sample taken 224 days after the event.	Tell worker to return to radiation work despite positive detection of plutonium-238, plutonium-239 and americium-241 in fecal sample taken 224 days after the event. Do not provide fecal bioassay result to worker. Basically, ignore the implications of the high fecal bioassay result in the dose assessment.
Chelation Enhancement Factor	A proper response would be to admit the difficulty of assessing the effect of one single chelation treatment, administered at 4 hours after the event, particularly when the more soluble Am-241 would be in blood stream and	Use chelation potential effect to reduce urine sample intake estimates.

Method	What Should Be Done, and As-Found Status	What BEA Did and What BEA Reported
	urine sample results for Am-241 destroyed.	
Inhalation or ingestion dose	A proper response would be to use positive bioassay at 224 days after the intake as knowledge of a predominantly inhalation event.	Assume a significant portion of the intake was ingestion rather than inhalation. Assert that there was "face touching" etc. that caused ingestion despite video evidence confirming that no such behavior occurred.
Solubility study and particle size	A proper response would be to conduct solubility study of adequate duration and conduct particle size determination and acknowledge differences over time in material properties versus immediately upon release from being wrapped in plastic.	Conduct shortened solubility study. Do not conduct particle size determination. Do not consider oxidation post-event that alters estimate of actual inhalation. Ignore the Pu and Am hydride forms.
Type M versus Type S solubility class	A proper response would be to conduct defensible evaluation of solubility of americium-241 and plutonium-239 and examine bioassay results for in vivo agreement.	Determination of Type S in order to apply to lowest Dose Conversion Factor. Ignore higher Am-241 in urine samples, which differs from ratio of Pu-239 to Am-241 in most fecal samples.
Medical assistance.	A proper response would be to provide competent medical assistance.	Tell medical personnel that the nasal swab was only 150 dpm and that the lung count detection of Am-241 meant no plutonium was present in the lungs. Pay a DOE petri-dish and rat researcher who did not review any aspect of their bioassay results to reassure the workers that they are fine. He assumes the workers bioassays are negative, which is untrue. This clearly shows he had no knowledge of the worker's actual bioassay or intake

Method	What Should Be Done, and As-Found Status	What BEA Did and What BEA Reported
		levels.
Americium-241 ingrowth	A proper response would be to either use more conservative Type M for Am-241 or include Am-241 ingrowth from Pu-241 taken into the body.	Apply Type S Dose Conversion Factor and ignore Am-241 ingrowth from Pu-241 taken into the body.

Table notes:
a. Collect vomit in addition to urine and fecal samples, see https://ashpublications.org/hetatology/article/2003/1/473/18671/The-Hematologist-and-Radiation-Casualities.
b. See Health Physics Society https://hps.org/publicinformation/ate/q114031.html regarding inhaled material deposited in the posterior nasal passage and pharynx which travels through the small and large intestine to excretion.

If you read and understood what I've written in the table above, your outrage meter should have pegged. The actions taken by Battelle Energy Alliance to make it seem like the accident that they caused had no serious consequences would be criminal, except that this type of behavior is just business-as-usual for Department of Energy contractors.

Because the Department of Energy is responsible for approving the adequacy of the safety analysis of its nuclear facilities, it is relevant to note that the Department of Energy had officially approved all the nuclear facilities at the Idaho National Laboratory's Materials and Fuels Complex as 10 Code of Federal Regulations (CFR) 830 compliant before 2005. Battelle Energy Alliance took over as contractor at the INL in 2005. Then DOE determined that the safety analyses it had already approved did not meet the intent of 10 CFR 830 for nuclear safety at Department of Energy facilities. This required a multi-year, expensive effort to upgrade the safety analyses.

The DOE contractor is required, and specifically, each Nuclear Facility Manager designated by the contractor (Battelle Energy Alliance), is required to understand the safety analyses and approve the work procedures and instructions for conducting work safely at the facility.

The workers would repeatedly question whether to open the plastic to inspect the mixed oxide fuel plates known as Zero Power Physics Research Reactor (ZPPR) plutonium plates. The Facility Manager was consulted and along with the Shift Supervisor gave the instruction to workers to open the plastic and inspect the plutonium plates, despite the indications of damaged plates hand-written on labels on the plates.

A DOE-appointed review board would find that Battelle Energy Alliance ignored repeated warnings from its appointed Independent Safety Review Chairman of worker safety issues and

BEA could have prevented the accident that exposed a dozen workers to high levels of airborne radiological contamination. [9]

The Idaho National Laboratory Director, John Grossenbacher, would later state that **the workers** — who followed the BEA-appointed Nuclear Facility Manager's instructions, the BEA-appointed Shift Supervisor's instructions and adhered to the inadequately planned work approved by BEA — should have known better than to inspect the 30-year-old plates. **The exposed workers had no knowledge of the multiple safety analysis discrepancies or of the Independent Safety Review Chairman's warnings.**

After the accident, Battelle Energy Alliance would find that "Representatives from other DOE sites including Pacific Northwest National Laboratory (PNNL), Oak Ridge National Laboratory (ORNL) Y12 Facility, Washington Safety Management Solutions (WSMS), and the Savannah River Site (SRS) provided information regarding radiological work within fume hoods. **Although radioactive materials are routinely handled inside fume hoods, none of the sites indicated that handling of plutonium inside a fume hood is an acceptable or allowed practice at their facilities.**"

BEA would also discover that, unlike BEA's loose operational standards for the ZPPR hood, other DOE facilities require verification of proper airflow into the hood prior to conducting work in a hood — even for less hazardous materials inspected in their fume hoods.

For additional information on how Battelle Energy Alliance arrived at a radiation dose estimate for one worker at November 8, 2011 accident at the MFC ZPPR facility, see the slide presentation at the Environmental Defense Institute website. Based on the evidence, BEA's dose estimate is not credible. Also see the slide presentation for information about the lung counting conducted at the INL for this accident which points to lung count result manipulation to lower the result, and thus lowering the corresponding plutonium and americium intake estimate and lowering the radiation dose estimate. [10] [11]

[9] U.S. Department of Energy Office of Health, Safety and Security Accident Investigation Report, *Plutonium Contamination in the Zero Power Physics Reactor Facility at the Idaho National Laboratory, November 8, 2011*, January 2012.

[10] Tami Thatcher, Slide Presentation for Environmental Defense Institute, "Review of Ralph Stanton's Radiation Dose from the 2011 Plutonium Inhalation Event at the Idaho National Laboratory – Part 2," March 2022 at http://www.environmental-defense-institute.org/publications/PowerptLowDose.pdf

[11] Tami Thatcher, Slide Presentation for Environmental Defense Institute, "Review of Ralph Stanton's Radiation Dose from the 2011 Plutonium Inhalation Event at the Idaho National Laboratory – Part 1, Lung Counting," February/March 2022 at http://www.environmental-defense-institute.org/publications/PowerptLungCount.pdf

Dose Conversion Factors for Inhalation of Type S Plutonium and Americium Have Increased

Department of Energy plutonium and americium inhalation radiation doses from insoluble Type S material **have increased by a factor of about 2**, according to a 2019 report by the International Commission on Radiological Protection. [12]

Historically, most plutonium inhalation doses were associated with weapons grade plutonium at Department of Energy facilities including the former Rocky Flats weapons plant, the Hanford site in the state of Washington, the Y-12 Oak Ridge plant in Tennessee, the Los Alamos National Laboratory in New Mexico and the Savannah River Site in South Carolina. But not all plutonium and americium inhalation events are not necessarily similar to weapons grade plutonium. The 2011 plutonium inhalation event at the Idaho National Laboratory's Materials and Fuels Complex involving a plutonium mixed oxide plate at the Zero Power Physics Research Reactor (ZPPR). Radiation dose assessment for the 2011 accident assumed the material inhaled was Type S plutonium and americium.

The radiation dose assessment for the INL's 2011 accident at the Materials and Fuels Complex (MFC) assumed that the ZPPR mixed oxide plate was entirely Type S material rather than Type M which was normally assumed for the americium-241 portion of the dose. The dose predicted by Type M solubility is higher than for Type S solubility, as the higher solubility allows more material to be dispersed to bone and to the liver. And Department of Energy contractor Battelle Energy Alliance (BEA) also ignored the ingrowth of americium-241 from plutonium-241 retained in the body.

Highly insoluble weapons grade plutonium has less plutonium-241 to begin with and therefore less americium-241 ingrowth from plutonium-241 decay. But the mixed oxide fuel plate at the ZPPR facility had far more plutonium-241 than weapons grade plutonium.

The 2019 ICRP report for actinides noted that plutonium-239 combined with uranium compounds appear to have different characteristics in the human body than plutonium oxide alone.

In the 2019 International Commission on Radiological Protection report, the inhalation dose coefficients for highly insoluble plutonium isotopes (Type S), prevalent at Department of Energy facilities, have increased by a factor of 1.5 to 2.0 "because of the revision of the biokinetic models, and a better description of the radionuclide retention and distribution in tissues." This means that a worker's prior dose estimate may be low by a factor of 2. And in addition, the dose would be low due to unaccounted for americium-241 ingrowth from plutonium-241. The ZPPR

[12] International Commission on Radiological Protection, "Occupational Intakes of Radionuclides: Part 4, ICRP Publication 141. Ann. ICRP Volume 48, No. 2/3," 2019. ISSN 0146-6453. (Online report anib_48_2-3ICRPPart4.pdf). This series of reports replaces the ICRP Publication 30 series and Publications 54, 68, and 78 series.

plates had a very high amount of plutonium-241 relative to americium-241, as accounted for in 2011.

Plutonium may be encountered in a variety of chemical and physical forms, including oxides, metals, chlorides or nitrates, or other forms. Plutonium oxides (PuO_2) can be found in nuclear weapons materials or in mixed oxide (MOX) nuclear reactor fuels. The chloride or nitrate forms would typically be found at reprocessing facilities.

When plutonium-239 is created in a nuclear reactor by neutron absorption, plutonium-240 is also created. And the longer the neutron bombardment in a reactor, the more plutonium-240 and plutonium-241 are created, relative to the plutonium-239 created. Plutonium-241 has a relatively short radioactive half-life (14.4 years) and it decays to americium-241. Americium-241 is actually more deadly than plutonium-239 when inhaled, ingested or entering the body due to a wound.

At the former Department of Energy nuclear weapons plant in Colorado, the Rocky Flats Plant, workers were found by autopsy to show very long lung retention of plutonium, corresponding to very highly insoluble (Type S) plutonium materials. Type S plutonium in the lungs means long retention times of plutonium (and americium) in the lungs.

Mixed oxide fuels, however, can contain much higher plutonium-238 as well as americium-241 levels than weapons grade plutonium, and can behave as much more soluble material, according to the 2019 ICRP report on actinides. While typically still characterized at Type S material, the mixed oxide fuels resulted in greater translocation to systemic organs in the body — such as bone tissue and the liver. In fact, transfer to bone and to the liver was found to be greater for mixed oxide fuels than that of simply plutonium oxide.

Plutonium-238 oxide has been found to be more soluble than plutonium-239 oxide in the 2019 ICRP report [13] and this was also indicated by the disproportionately high plutonium-238 excreted in urine from the 2011 plutonium inhalation event at the Idaho National Laboratory.

Perplexingly, it is not just a question of whether a material is Type M or Type S. Both plutonium and americium may have a fraction of the material that behaves as Type S and a fraction of material that behave as Type M. The question is not simply of whether a material is Type S or Type M, and it also depends on the specific details of the material's composition and form.

Material such as mixed oxide fuel contained in an oxygen deprived environment may include oxides as well as hydrides, according to the DOE Investigation report for the November 8, 2011

[13] International Commission on Radiological Protection, "Occupational Intakes of Radionuclides: Part 4, ICRP Publication 141. Ann. ICRP Volume 48, No. 2/3," 2019. ISSN 0146-6453. (Online report anib_48_2-3ICRPPart4.pdf). This series of reports replaces the ICRP Publication 30 series and Publications 54, 68, and 78 series. (See pages 221, 222.)

accident at the INL. [14] However, after the material is stored before evaluation, it may not represent the chemical form that was predominately inhaled immediately after exposed to an oxygen-rich environment.

And even if a material, after oxidizing in an oxygen-rich environment, is later determined to be americium oxide of mostly Type S solubility characteristics, the ingrowth of americium-241 in the lungs or other tissues or organs in the body from the decay of plutonium-241 may be a more soluble Type M form, that yields a higher radiation dose in the body than that of Type S.

As I noted in the newsletter last month, the ingrowth of americium-241 in the body from the decay of plutonium-241 is often neglected in radiation internal dose assessment at Department of Energy facilities. The older dose conversion factors are provided in Table 2 and the new 2019 ICRP 141 dose conversion factors are provided in Table 3. The new ICRP 141 dose conversion factors are higher for insoluble Type S materials.

Table 2. ICRP 78 dose conversion factors (DCF) for plutonium and americium-241.

DCF	Pu-238	Pu-239	Pu-240	Pu-241	Am-241
Type M DCF, (rem/curie)	1.10E+8	1.20E+8	1.20E+8	2.20E+6	1.00E+8
Type S DCF, (rem/curie)	4.10E+7	3.10E+7	3.10E+7	3.10E+5	3.18E+7

Table notes: Type M and Type S refer to material solubility, with Type M being moderately soluble and Type S being insoluble. Values from International Commission on Radiological Protection (ICRP) 78.

Table 3. Newer 2019 ICRP 141 dose conversion factors (DCF) for plutonium and americium-241.

DCF	Pu-238	Pu-239	Pu-240	Pu-241	Am-241
Type M DCF, (rem/curie)	4.44E+7	5.18E+7	5.18E+7	4.81E+5	2.96E+7
Type S DCF, (rem/curie)	8.51E+7	9.25E+7	9.25E+7	1.63E+6	6.29E+7

Table notes: Type M and Type S refer to material solubility, with Type M being moderately soluble and Type S being insoluble. Values from International Commission on Radiological Protection (ICRP) 141.

The 2019 ICRP 141 doses for plutonium and americium ingestion (rather than inhalation) dose conversion factors were reduced from previous DCFs.

[14] U.S. Department of Energy Office of Health, Safety and Security Accident Investigation Report, *Plutonium Contamination in the Zero Power Physics Reactor Facility at the Idaho National Laboratory, November 8, 2011*, January 2012.

Which is worse? A plutonium intake or an americium intake?

Plutonium is infamous for being harmful when taken into the body, by inhalation, ingestion or by wound entry. Often the focus has been on the lung cancer-causing ability of highly insoluble particles of plutonium have been inhaled by workers at nuclear weapons production facilities operated by the Department of Energy.

On the other hand, americium is less well known. Its name sounds nice. And it is used in smoke detectors.

People tend to think that americium is less harmful than plutonium. But they are wrong.

Both plutonium-239 and americium-241 are predominantly alpha particle emitters and mainly a hazard when taken into the body. Both target bone, liver, and lung organs. But americium-241 also gives off a 59.5 kiloelectron volt (keV) gamma ray in about 36 percent of its decays.

The radioactive half-life of Am-241 is 433 years, while that of Pu-239 is 24,000 years, making the plutonium-239 seem worse. But americium-241 decays into neptunium-237 which has a radioactive half-life of 2.1 million years.

In far less americium-241 (by weight), americium-241 yields the same number of radioactive decays per second as plutonium-239. The specific activity of Am-241 is 3.5 curies per gram, while the specific activity of Pu-239 is 0.063 curies per gram. **This means that 1 nanocurie (nCi) of Pu-239 would weigh 0.0159 micrograms and the same activity of Am-241 would weigh 0.000286 micrograms, over 55 times less by weight.**

And, if we look at the radiation dose conversion factors for americium-241 and plutonium-239, we would see slightly higher whole-body doses from Am-241 than Pu-239, by activity inhaled. For Type S insoluble material, the organ/tissue doses are very similar, with americium-241 yielding higher doses for all organs and tissues except for the liver and red bone marrow dose which was higher for Pu-239. (This was based on the organ/tissue dose conversion factors prior to 2019.) Moderately soluble Type M materials give higher radiation doses than Type S. Retention of plutonium and americium in the body has been found to be higher than earlier estimates and as noted in the previous article, the radiation dose coefficients for Type S, highly insoluble material, were found to have increased from previous estimates.

For both plutonium and americium, the main sites of deposition of activity in the blood stream are bone surfaces and liver. The bone surface deposition “is tenaciously retained” until removal by bone restructuring processes. The activity removed from bone surfaces is recycled and may move in the bone volume, may transfer to blood and to bone marrow. The distribution of plutonium differs from americium, with plutonium deposits mainly on endosteal surfaces. The americium deposits to a much greater extent than plutonium on cortical vascular channels. Like

plutonium, americium is highly retained in the body and is recycled in the body with less excretion via urine, in the long term, than previously thought. [15]

Plutonium in the liver is thought to be retained for years, decades, in humans and thought to be retained longer than for americium.

The good news in the 2019 ICRP report was that they found that the biological removal half time of plutonium or americium from gonads (ovaries and testes) was reduced from 10 years to 5 years. The bad news is that you don't want either plutonium or americium in your gonads at all. Alpha particle radiation is **high linear energy transfer**, or high-LET radiation relative to beta particles, and is more able to cause double-strand breaks in DNA. These breaks may be mis-repaired, joining the broken parts together but not correctly.

The unstated intakes of plutonium-241 associated with forms of plutonium having spent more time in a nuclear reactor add to the ingrowth of americium-241 which builds up in the material before inhaled, and continue to build up once inside the body.

Both plutonium and americium are made in a nuclear reactor. When plutonium-239 is produced in a reactor, plutonium-240 and plutonium-241 are also produced. The longer plutonium-240 is in a reactor, the more plutonium-241 is produced relative to plutonium-239. Plutonium-241 decays to americium-241. And plutonium-241 inhaled into the body which decays to americium-241 would be a more soluble form even if the plutonium inhaled was very insoluble oxide particles. Because plutonium-241 is a beta emitter, with a lower dose coefficient than plutonium-239, it has often been ignored in radiation dose assessment despite the dose from its decay progeny, americium-241.

General government publications have stated that very little americium-241 is created by the nuclear industry, which by weight might be true. More grams of plutonium-239 are produced. But the radioactivity of americium-241 created reactors, through its ingrowth from the decay of plutonium-241, within 70 years of removal from a reactor will far eclipse the radioactivity of the plutonium-239 created. And the higher burnup fuels create more plutonium and more americium than the earlier lower-enriched fuels.

Which is worse, an intake of plutonium-239 or americium-241? Americium-241 is worse. And its ingrowth from plutonium-241 inside the body has often been ignored in plutonium dose assessment.

And not only that, some communities such as those surrounding the Idaho National Laboratory, are being bathed in ongoing airborne americium and plutonium releases from Department of Energy americium target material operations, waste handling and other operations. Americium-241 brought to the INL for burial from the Rocky Flats nuclear weapons

[15] International Commission on Radiological Protection, "Occupational Intakes of Radionuclides: Part 4, ICRP Publication 141. Ann. ICRP Volume 48, No. 2/3," 2019. ISSN 0146-6453. (Online report anib_48_2-3ICRPPart4.pdf). This series of reports replaces the ICRP Publication 30 series and Publications 54, 68, and 78 series. (See pages 221, 222.)

plant have been released by Radioactive Waste Management Complex disposal area flooding, by exhumation, and general fugitive releases through the years, which for many decades were not reported.

See our recent report, *Airborne Radiological Releases from the Idaho National Laboratory and the Increasing Radioactive Contamination in Southeast Idaho,* for trends in DOE's reported INL radiological airborne effluent releases, the Department of Energy's estimated effective whole-body dose from the airborne releases, and the levels of radioactive contamination in air, milk, lettuce, wheat and soil from the DOE's environmental surveillance program. [16]

Hemopoietic Syndrome from Inhalation of Plutonium or Americium Causes a Drop in Blood Lymphocytes, But Rarely Studied

Radiation dose estimates are primarily used to estimate the risk of fatal cancers, with small numbers of lung and bone cancers noted among plutonium workers, many of whom, in the past, were also smokers. The nuclear industry exclusive focus on cancer fatalities from radiation exposure continues to obscure the damage to blood-forming stem cells in bone marrow, which make up the body's immune system, in the short term and also in the long term, following the intake of actinides such as plutonium and americium.

Autopsy results showing high retention of plutonium in the lungs and the focus on lung cancer would make it seem that inhaling insoluble Type S plutonium-239 would be worse than inhaling americium-241. But the differences in the actual damage to bone marrow stem cells and to the human immune system has not been studied. And death due to anything other than lung or bone cancer is not attributed as a possibility from the plutonium or americium intake.

While the concern over the long term has been for causing lung and bone cancer, in the short term, peripheral blood changes have been documented in dogs. [17] For some reason, it is very difficult to find documentation of blood changes from plutonium or americium intakes in humans, despite considerable human testing, sometimes conducted without consent. I am referring to the Atomic Energy Commission and Department of Energy Human Radiation Experiments described in Eileen Welsome's book *The Plutonium Files – America's Secret Medical Experiments in the Cold War*, The Dial Press, 1999.

It is far easier to find depictions of blood changes, such as the sharp drop in lymphocytes, from radiological exposures that were predominantly external radiation exposures. The acute radiation exposure to five people exposed to a criticality in 1958 at the Y-12 plant at Oak Ridge

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[16] Special Report, Environmental Defense Institute, *Airborne Radiological Releases from the Idaho National Laboratory and the Increasing Radioactive Contamination in Southeast Idaho*, December 2021 by Tami Thatcher at http://www.environmental-defense-institute.org/publications/INLcontamination.pdf

[17] Dr. O. Vanderborght, University of Antwerpen, *Study of Murine Stroma in Fetal and Postnatal Haemopoietic Organs and After Radiocontamination with 241-Americium in Utero and as Adults*, 1990. At IAEA INIS repository.

estimated doses of 236 to 365 rad. Blood draws were taken and trended over 60 days. [18] The estimated radiation doses are not accurate, and there were likely internal intakes that were not characterized.

Bone marrow has long been known to be sensitive to radiation effects and it is the dose to the red bone marrow that is used to estimate the extent of hemopoietic syndrome. An external dose of 100 rad to the red bone marrow is considered the threshold of severe deterministic effect from hemopoietic syndrome. [19] In the case of external dose, 100 rad is equal to 100 rem.

Far less **absorbed dose** to the red bone marrow from internal plutonium or americium is needed to reach the threshold of severe hemopoietic syndrome than from the absorbed dose due to external radiation. **Only 20 rad absorbed dose (but only the weighted RBE absorbed dose) from internal dose to red bone marrow for the estimated threshold of severe hemopoietic syndrome, 5-fold less than the external absorbed dose of 100 rad to red bone marrow.** The red bone marrow doses for severe deterministic effects are from International Atomic Energy Agency General Safety Guide GSG-2.

But for internal alpha-emitters plutonium and americium, absorbed dose is not equal to the equivalent organ dose typically provided in a dose assessment. The estimated equivalent organ dose for alpha uses a radiation weighting factor of 20; therefore, the absorbed dose is 20 times less than the equivalent organ dose. Then, GSG-2 says to multiply the absorbed dose by an RBE of 2. Thus, an RBE-weighted dose specifically for hemopoietic syndrome must be derived and is to be derived over a 30-day period, rather than a 50-year period that equivalent organ doses are generally stated. Since the dose estimations for an inhalation of plutonium or americium may require urine and fecal analysis and may take months of time for an internal dosimetrist to decipher, good luck determining your 50-year committed equivalent red bone marrow dose, let alone your 30-day equivalent red bone marrow dose, anytime soon after an inhalation event.

And while the lung count results have the capability to estimate the americium-241 in the lungs, those lung reports can be manipulated without documentation of peak deletion or other tactics. To determine the dose from the lung count result for Am-241, you must know the composition of the material inhaled, (how much plutonium-239 relative to Am-241), the solubility of the material, the particle size, acute versus chronic inhalation, and the time of the inhalation. Again, good luck determining your whole-body dose let alone your red bone marrow dose, after your lung count. Department of Energy sites like the Rocky Flats Plant sometimes didn't even tell workers their lung count results indicated a high intake. And recounts of lung counting at Rocky Flats happily nearly always returned the result that no intake had occurred. Lung counts have high detection capability, but cannot be relied upon to be conducted in an

[18] Herman Cember, *Introduction to Health Physics, Second Edition*, McGraw-Hill, 1992.ISBN-0-07-105256-9.
[19] International Atomic Energy Agency, General Safety Guide No. GSG-2, *Criteria for Use in Preparedness and Response for a Nuclear Radiological Emergency*, 2011. See Table 2.

ethical manner, see my presentation on lung counting. [20] Blood drawn for a Complete Blood Count (CBC) is needed and needs to be repeated to be trended over the days following the inhalation.

Essential to determining whether or not a plutonium or americium inhalation could pose severe deterministic effect from hemopoietic syndrome is knowledge of the particle size and solubility of the inhaled material. **The difference in the dose to red bone marrow may be on the order of 10 times higher for Type M versus Type S (insoluble) material.**

Something on the order of inhaling 1453 nanocuries of americium-241, just 0.4 micrograms, may be near the hemopoietic syndrome, (but I'm lacking 30-day red bone marrow doses). In fact, organ dose conversion factors are not readily available online. Bone marrow depression and then complete bone marrow ablation would occur at higher doses. Bone marrow transplants have rarely been effective because of the very high doses involved before bone marrow transplant is needed mean that the patient has little chance of survival.

Blood changes, including a sharp drop in blood lymphocytes is an indication of the damage to and the dose to the red bone marrow. Trending blood counts is needed after a serious inhalation event, particularly when the material might include a considerable portion of highly soluble (Type M) material. Lymphocyte depression, though not meaning that a bone marrow transplant is needed, can still have adverse health effects and be detrimental to the immune system.

Most of the publications I found that pertained to radiation deterministic effects ignored the possibility of a large enough plutonium or americium inhalation to cause hemopoietic syndrome. Those that did, usually focused on Type S insoluble plutonium oxide inhalation, which would require 10 times more activity to be inhaled than for Type M material. And remember, the same activity of americium would be inhaled in 1/50th of the mass of the amount of plutonium.

There is little documentation of the blood changes such as the drop in lymphocyte counts, resulting from americium or plutonium inhalation. I found citations referring to studies for dogs, but could not obtain the actual documents. The scantness of human studies published pertaining to hemopoietic syndrome from inhalation of americium and plutonium must be noted.

Articles by Tami Thatcher for April 2022.

[20] Tami Thatcher, Slide Presentation for Environmental Defense Institute, "Review of Ralph Stanton's Radiation Dose from the 2011 Plutonium Inhalation Event at the Idaho National Laboratory – Part 1, Lung Counting," February/March 2022 at http://www.environmental-defense-institute.org/publications/PowerptLungCount.pdf