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July 11, 2016

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Subject: Public Comment for inclusion in the public record on US Department of Energy (DOE) Application to renew the Calcined Solids Storage Facility Mixed Hazardous Waste Permit (EPA ID No. ID4890008952) (Docket No. 10HW-1604)

The Idaho Department of Environmental Quality (IDEQ) must look beyond the vague and oversimplified statements being trumpeted in the Leadership in Nuclear Energy Commission (LINE commission) reports regarding the calcine stored at the Idaho National Laboratory (INL). With no explanation of the hazards posed by the continued storage of high-level waste calcine material at the INL, the LINE reports downplay the risk of storing the calcine and the reality of having no designated repository to ship the calcine to. The composition of the calcine is presented here along with brief description of the hazard posed. The calcine inventory is compared to buried waste at the INL's Radioactive Waste Management Complex (RWMC) that will stay buried, and also to the planned replacement facility for the RWMC. The seismic vulnerability of the calcine storage is then described.

The 1995 Idaho Settlement Agreement [1] requires packaging of the calcine in order to ship it and requires shipping the calcine to an as of yet unidentified repository by 2035. IDEQ needs to plan for the contingency that the DOE is tardy, and must address seismic weakness of the calcine storage, rather than allow the lack of a repository for the calcine high level waste to become an excuse to delay repackaging of the calcine to a road-ready condition.

The LINE Commission 2013 report [2] makes the strong push for Idaho to put repackaging of

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

[2] See the Leadership in Nuclear Energy Commission reports and the 2013 report at LINE Exec Summary: http://gov.idaho.gov/mediacenter/press/pr2015/pdf/LINE%20Exec%20Summary.pdf The LINE commission report narrative downplays the hazards posed and the lack of a designated repository for permanent disposal of calcine, arguing instead for the State of Idaho to ignore the calcine, delay repackaging and forget about the 1995 Idaho Settlement Agreement. Specifically, the 2013 LINE report states: "Thus, the state should be open to alternative approaches for the calcine; this could include the possibility of keeping the calcine in its current, safe storage configuration so long as any change in plans brought commensurate value to the state of Idaho, such as redirecting the funds saved to other INL [research] projects."

the calcine behind research funding for the INL. The LINE Commission report fails to represent the interests of Idahoans and does not disclose how continued calcine storage leaves Idaho vulnerable to accidents including severe Natural Phenomena Hazards events that can cause release of the calcine. The serious hazard posed by calcine waste storage is not discussed in any meaningful way but is instead waived away in LINE presentations and is not presented in IDEQ distributed literature concerning the calcine. The presumed low risk is not backed up by any meaningful disclosure of an adequate risk analysis. Idahoans must examine the facts.

While it is significant that the 4,400 cubic meters of calcine granular solids is not currently leaching into the aquifer, numerous buried waste sites at INL have leaked and are leaking and the INL's INTEC liquid high-level waste (HLLW) tank farm and other INTEC locations have leaked radionuclide and chemical contamination into soil and the Snake River Plain aquifer. It is important to recognize the extraordinary high quantity of calcine high-level waste generated from reprocessing SNF producing 7,733,000 gal. (29,280,000 L) of HLLW. [3] That is essentially an enormous amount of spent nuclear fuel minus the uranium-235 and volatiles. The hazard posed by over 30 million curies [4] of highly soluble and readily dispersible form of the calcine material must be respected. The **basic inability to mitigate a release from a calcine bin set must be recognized and emphasized** along with recognition of the inevitable far-reaching devastating **long-term environmental consequences that cannot be remediated** should a serious breach of one or calcine bin sets occur.

While the calcine bin sets are not in the dire shape of leaking tanks at Hanford, LINE Commission speakers should not placate Idahoans with comparisons of Idaho's waste problems to the already horrible and continuing to deteriorate state of environmental devastation at Hanford's DOE waste site that will never be remediated. Calcine blowing in the wind, with its powdered laundry detergent granularity, would be difficult or impossible to remediate. **IDEQ must require the DOE to put the calcine into a less vulnerable condition and must do so with more urgency, not less, because of the lack of a designated repository for the high-level calcine waste.**

The DOE emphasizes that the bulk of the calcine radioactivity will decay away in a few hundred years; there are 33.1 million curies (assuming decay to 2016). The strontium-90 and cesium-137 do make up the bulk of the radioactivity, driving shielding needs and do pose a huge environmental hazard if released now. But often ignored in presentations to the public is the toxicity over millennia from other radioisotopes in the calcine, should they be allowed to migrate to the aquifer. If calcine were allowed to leach into soil from the vaults containing the bin sets, the

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[3] U.S. Nuclear Waste Technical Review Board, "Calcined High-Level Radioactive Waste," Factsheet. http://www.nwtrb.gov/facts/Calcined_HLW.pdf

[4] Ibid. The NWTRB states 31 million curies based on the value given in Carter *et al.* (2013, Table F-1), decay corrected to January 1, 2017 but we otherwise cite the 33.1 million curies based on DOE/EIS-0287, decay corrected to 2016.

calcine will leach into the aquifer. There would, realistically, be no cleaning up the contamination. Once in the aquifer, the contamination flows downstream to communities, even if the contamination lies deeper in the aquifer than is typically monitored or acknowledged.[5]

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

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

Table 2 provides some additional perspective on the large inventory of radioactive material in the Table 1. Calcine bin set total radionuclide inventory comparison to the waste that will remain buried at RWMC and to the replacement for RWMC.

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

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

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

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

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

Radionuclide (half life)	**Calcine Inventory (curies)**	**Buried (existing) RWMC Inventory (curies)**	**Buried (future) Replacement RH-LLW Inventory (curies)**
Carbon-14 (5730 year)	0.038	731	432
Chlorine-36 (301,000 year)	0	1.66	260
Iodine-129 (17,000,000 year)	**1.6**	0.188	0.133
Technetium-99 (213,000 year)	**4600**	42.3	16.7
Neptunium-237 (2,144,000 year)	**470**	0.141	0.003
Uranium-232 (68.9 year)	1.6	10.6	0.00036
Uranium-233 (159,000 year) Product bred from U-235 and thorium, also decay of Np-237	0.057	2.12	0.0001
Uranium-234 (245,500 year) Pu-238 decay product	**130**	63.9	0.0012
Uranium-235 (703,800,000 year)	**3.2**	4.92	0.005
Uranium-236 (23,400,000 year) Pu-240 decay product	**11**	1.45	0.0001
Uranium-237 (0.0185 year to Np-237)	**1.5**	-	-
Uranium-238 (4,470,000,000 year)	3.1	148	16.2
Thorium-228 (1.92 year to radium-224) Natural thorium decay and Pu-240 decay product	1.6	10.5	-
Americium-241 (423 y decays to Np-237)	12,000	215,000	0.38
Plutonium-238 (87.7 year)	**110,000**	2080	-
Plutonum-239 (24,000 year)	**48,000**	64,100	-

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

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

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

Radionuclide (half life)	Inventory (curie)	Maximum Contaminant Level	Dilution volume (Liter) [b]	Number of Aquifers to Dilute
Sr-90/Y-90 (Sr-90 29.1 year)	15,800,000	8 pCi/L	1.975E+18 1,975,000,000 billion	809
Cs-137/Ba-137m (30.2 year)	17,300,000	160 pCi/L	1.081E+17 108,000,000 billion	44
C-14 (5,730 yr)	0.038	2000 pCi/L	1.90E+7 0.019 billion	<<1
Cl-36 (301,000 yr)	0	700 pCi/L	0	0
I-129 (17,000,000 yr)	1.6	1 pCi/L	1.6E+12 1600 billion	<<1
Tc-99 (2213,000 yr)	4600	900 pCi/L	5.11E+12 5110 billion	0.002
Np-237 (2,144,000 yr)	470	15 pCi/L[a]	3.13E+13 31,300 billion	0.0128
U-234 (245,500 yr)	130	15 pCi/L[a]	8.67E+12 8,670 billion	0.00355
Am-241 (432 yr to Np-237)	12,000	15 pCi/L[a]	8.0E+14 800,000 billion	0.378
Plutonium-238 (87.7 year)	110,000	15 pCi/L[a]	7.3E+15 7,300,000 billion	3
Plutonum-239 (24,000 year)	48,000	15 pCi/L[a]	3.2E15 3,200,000 billion	1.3

a. The unit of 1 picoCurie/liter is 1.E-12 curie/liter. The limit is 15 pCi/L for total alpha (40 CFR 141). For uranium, total natural uranium limit of 30 microgram/liter for all combined uranium isotopes.
b. Aquifer volume of 2.44E+15 liters is assumed.
c. The dilution volume ignores soil adsorption and migration delay timing; it is provided to give some perspective on the amount of waste involved. It ignores that fact that the entire aquifer is not going to be involved with dilution, although waste in the aquifer can fan out and involve a considerable portion of the aquifer downstream.

calcine bin sets. It would require 1,975,000,000 billion liters of water (or over 800 Snake River Plain aquifers) to dilute the strontium-90/y-90 in calcine storage to federal drinking water standards. It would require 7,300,000 billion liters of water (or over 3 Snake River Plain aquifers) to dilute the Pu-238 stored in the calcine to federal drinking water standards. It should also be pointed out that these figures are presented as though only a single contaminant were present. In reality, the health detriment of the combination of all contaminants in the drinking water must be considered. This is a point often overlooked by the Idaho Department of Environmental Quality as IDEQ surveys the contamination in the aquifer, dismissing any result below federal drinking water standards which have, for tritium and hexavalent chromium been found to not be protective of human health, especially when consumed over a lifetime. [10] The graph of the migration of the

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

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

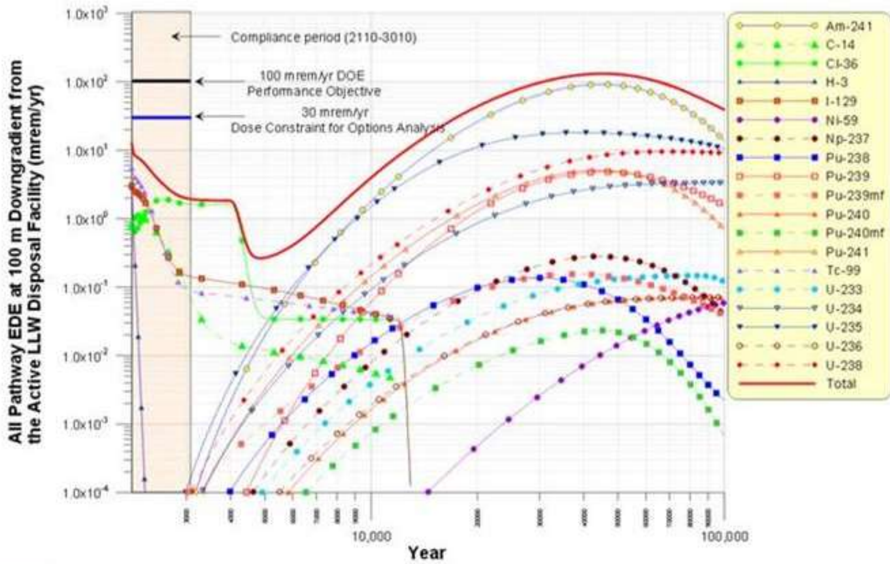

Figure 4-2. All-pathways effective dose equivalent 100 m downgradient from the Radioactive Waste Management Complex boundary from year 2110 to year 100,000 with cover infiltration rate equal to 1 cm/year.

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

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

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

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

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

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

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

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

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

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

The charade continues to this day concerning the seismically weak calcine bin set 1 (both bin set and also the vault). The ability of the vault to withstand a PC-2 seismic event does not alleviate the problem that bin set 1 is expected to not withstand even a small and likely PC-2 seismic event and the spilled calcine in the concrete vault will not be confined by the vault. It should be obvious why the hand waving occurs during LINE Commission meetings rather than facts about the seismic vulnerability of the calcine bin sets, in particular, bin set 1.

Design standards for pre-1990 tank structures constructed at the INL have typically been found to be seismically inadequate. Despite pressure to find otherwise, it appears highly questionable whether the early calcine bin sets would be capable of withstanding any anticipated or likely seismic event. Given the extremely large inventory of hazardous material, the release of which cannot be remediated, it would be much more appropriate for the interests of protecting Idaho to require a higher level of seismic capability to withstand a more serious seismic event.

Structural consensus codes and standards have changed substantially since the bin sets were originally commissioned, especially for calcine bin sets and vaults 1 through 3. An unbiased assessment of the calcine bin sets is likely to conclude that one seismic event centered near the INTEC site that approaches the magnitude of historical seismic events in the area, will likely result in spilling highly radioactive calcine across the Idaho desert, which can then be dispersed to populated areas via prevailing winds. The IDEQ needs to recognize the serious seismic vulnerability of the calcine storage at the INL and must refuse to accept inadequately supported seismic analyses that do not use evaluation to standards commensurate with the long-term environmental hazard posed to the environment by a release of the calcine.

In December 2009, DOE issued a Record of Decision (75 Federal Register 137) documenting the selection of hot isostatic pressing (HIP) technology to convert the granular calcine into a glass ceramic waste form. In the HIP process, calcine and ceramic-forming chemical additives would be mixed and then loaded into thin-walled canisters that would be welded shut. These canisters would then be placed in a pressure vessel that would be heated to "melt" the mixture while pressurized with argon gas. The net effect would be production of a homogeneous glass ceramic waste form that reduces the original volume by approximately 30% and generates no secondary waste stream. Glass ceramics have properties similar to HLW borosilicate glass. [14]

The repackaging of the INL's calcine using HIP would put the calcine into a substantially safer waste form that would remove the possibility of calcine blowing in the wind and alleviate the seismically vulnerable bin set and vault calcine storage currently used at the INL. IDEQ must require expedited repackaging of the calcine stored at the INL even if shipment of the calcine is not expected to occur in time to meet the 2035 shipment milestone stipulated in the Idaho Settlement Agreement.

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[14] US Nuclear Waste Technical Review Board, "Calcined High-Level Radioactive Waste" Factsheet. http://www.nwtrb.gov/facts/Calcined_HLW.pdf

Respectfully Submitted,

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Appendix C.7 - ***New Information*** -

Table C.7-2. Bin set total chemical inventory (fission and activation species decayed to 2016).[a]

Constituent	Total mass (kg)	Constituent	Total mass (kg)
Actinium	1.2×10^{-6}	Molybdenum	2.9×10^{4}
Aluminum	9.7×10^{5}	Neodymium	1.4×10^{3}
Americium	4.4	Neptunium	46
Antimony	10	Nickel	2.6×10^{3}
Arsenic	3.7	Niobium	2.6
Astatine	8.5×10^{-20}	Palladium	110
Barium	770	Plutonium	1.3×10^{3}
Beryllium	3.6	Polonium	2.8×10^{-9}
Bismuth	2.7×10^{-9}	Potassium	2.8×10^{4}
Boron	4.0×10^{4}	Praseodymium	380
Bromine	29	Promethium	5.7×10^{-3}
Cadmium	4.7×10^{4}	Protoactinium	2.4×10^{-3}
Calcium	1.1×10^{6}	Radium	2.7×10^{-5}
Californium	1.0×10^{-12}	Rhodium	140
Cerium	850	Rubidium	170
Cesium	740	Ruthenium	1.9×10^{3}
Chlorine	4.5×10^{3}	Samarium	280
Chromium	8.8×10^{3}	Selenium	51
Cobalt	1.6	Silver	8.3
Curium	3.6×10^{-3}	Sodium	1.3×10^{5}
Dysprosium	3.3	Strontium	2.6×10^{3}
Erbium	1.8	Technetium	280
Europium	20	Tellurium	140
Fluorine	8.4×10^{5}	Terbium	0.94
Francium	3.1×10^{-14}	Thallium	0.36
Gadolinium	15	Thorium	6.1
Gallium	14	Thulium	0.14
Germanium	1.2	Tin	43
Holmium	1.1	Uranium	1.7×10^{4}
Indium	4.0	Ytterbium	1.8
Iodine	1.4×10^{3}	Yttrium	260
Iron	2.2×10^{4}	Zinc	71
Lanthanum	440	Zirconium	5.6×10^{5}
Lead	360	NO_3	2.5×10^{5}
Lithium	18	PO_4	2.4×10^{4}
Manganese	1.2×10^{3}	SO_4	5.3×10^{4}
Mercury	1.2×10^{4}		

a. Source: Valentine (2000).

Table C.7-3. Bin set total inventory of radionuclides (decayed to 2016).[a]

Constituent	Total activity (Ci)	Constituent	Total activity (Ci)	Constituent	Total activity (Ci)
H-3	15	Sm-148	9.0×10^{-9}	Th-227	0.085
Be-10	0.033	Sm-149	2.9×10^{-9}	Th-228	1.6
C-14	0.038	Sm-151	4.5×10^{5}	Th-229	1.4×10^{-4}
Co-60	1.5×10^{3}	Eu-150	5.3×10^{-3}	Th-230	1.4
Ni-63	6.8×10^{4}	Eu-152	430	Th-231	5.0
Se-79	9.9×10^{4}	Gd-152	5.3×10^{-10}	Th-232	2.3×10^{-7}
Rb-87	9.1×10^{-3}	Eu-154	2.9×10^{4}	Th-234	5.0
Sr-90	7.9×10^{6}	Eu-155	3.9×10^{3}	Pa-231	0.11
Y-90	7.9×10^{6}	Ho-166m	0.014	Pa-233	690
Zr-93	680	Tm-171	1.1×10^{-9}	Pa-234m	5.0
Nb-93m	630	Tl-207	0.085	Pa-234	6.3×10^{-3}
Nb-94	270	Tl-208	0.16	U-232	1.6
Tc-98	7.3×10^{-4}	Tl-209	1.9×10^{-6}	U-233	0.057
Tc-99	4.6×10^{3}	Pb-209	1.4×10^{-4}	U-234	130
Rh-102	9.1×10^{-3}	Pb-210	0.013	U-235	3.2
Ru-106	4.4×10^{-3}	Pb-211	0.085	U-236	11
Rh-106	0.029	Pb-212	1.6	U-237	1.5
Pd-107	9.1	Pb-214	0.027	U-238	3.1
Ag-108	1.1×10^{-5}	Bi-210m	5.2×10^{-17}	U-240	1.6×10^{-7}
Ag-108m	1.3×10^{-4}	Bi-210	0.013	Np-235	5.1×10^{-17}
Ag-109m	3.8×10^{-17}	Bi-211	0.085	Np-237	470
Cd-109	3.8×10^{-17}	Bi-212	1.6	Np-238	0.017
Cd-113m	1.6×10^{3}	Bi-213	1.4×10^{-4}	Np-239	50
In-115	2.7×10^{-8}	Bi-214	0.027	Np-240m	1.6×10^{-7}
Sn-121m	68	Po-210	0.013	Pu-236	0.027
Te-123	1.3×10^{-10}	Po-211	1.7×10^{-4}	Pu-238	1.1×10^{5}
Sb-125	130	Po-212	0.29	Pu-239	4.8×10^{4}
Te-125m	38	Po-213	1.4×10^{-4}	Pu-240	2.0×10^{3}
Sn-126	310	Po-214	0.027	Pu-241	4.8×10^{4}
Sb-126	43	Po-215	0.085	Pu-242	130
Sb-126m	310	Po-216	1.6	Pu-243	1.1×10^{-13}
I-129	1.6	Po-218	0.027	Pu-244	1.6×10^{-7}
Cs-134	67	At-217	1.4×10^{-4}	Am-241	1.2×10^{4}
Cs-135	360	Rn-219	0.085	Am-242m	6.1
Cs-137	8.8×10^{6}	Rn-220	1.6	Am-242	5.8
Ba-137m	8.5×10^{6}	Rn-222	0.027	Am-243	50
La-138	6.8×10^{-8}	Fr-221	1.4×10^{-4}	Cm-242	4.8
Ce-142	9.4×10^{-3}	Fr-223	0.018	Cm-243	5.0
Ce-144	8.6×10^{-5}	Ra-223	0.085	Cm-244	250
Pr-144	1.4×10^{-3}	Ra-224	1.6	Cm-245	0.071
Pr-144m	1.7×10^{-5}	Ra-225	1.4×10^{-4}	Cm-246	4.6×10^{-3}
Nd-144	4.6×10^{-7}	Ra-226	0.027	Cm-247	5.2×10^{-9}
Pm-146	2.3	Ra-228	2.3×10^{-7}	Cm-248	5.5×10^{-9}
Pm-147	5.3×10^{3}	Ac-225	1.4×10^{-4}	Cf-249	4.0×10^{-9}
Sm-146	8.6×10^{-5}	Ac-227	0.085	Cf-250	1.7×10^{-9}
Sm-147	3.0×10^{-3}	Ac-228	2.3×10^{-7}	Cf-251	6.3×10^{-11}

a. Source : Valentine (2000).

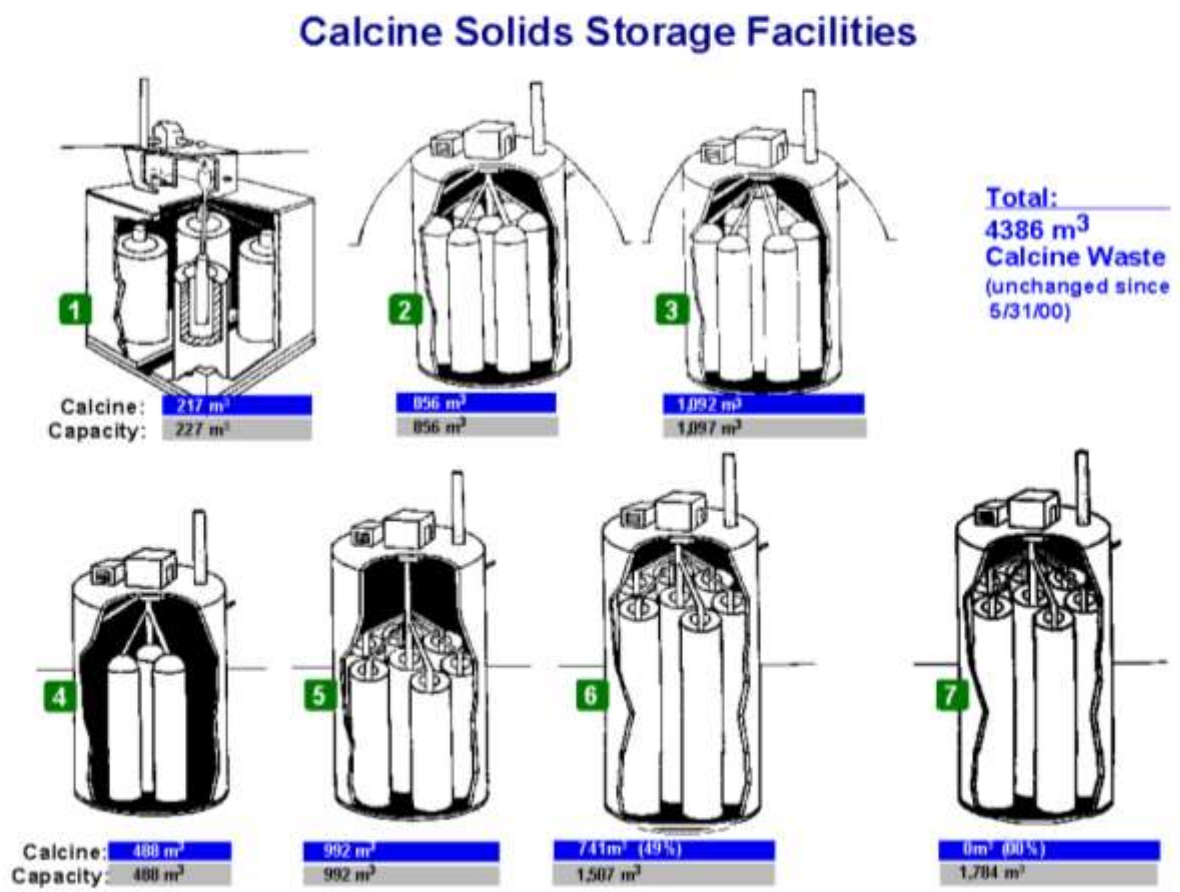

Figure A1. Calcine Solids Storage Facilities from INEEL/EXT-02-01548.