Plutonium Wastes from the U.S. Nuclear Weapons Complex

by Robert Alvarez, Senior Scholar, Institute for Policy Studies, Washington, D.C. July 7, 2010

Summary

Characterization of radioactive wastes at nuclear weapons sites can reduce fissile material uncertainties necessary for deep nuclear arms reductions while serving to protect the human environment. In this regard, a preliminary estimate based on waste characterization data indicates that from 1944 to 2009 about 12.7 metric tons of plutonium was discarded at U.S. nuclear weapon production facilities. This is more than three times than the U.S. Department of Energy's (DOE) last official estimate of waste losses (3.4 tons) made in 1996. Of the 12.7 tons, about:

- 2.7 tons in high-level radioactive wastes are stored as liquids in tanks and as granulated material in bins on the sites of former U.S. military reprocessing plants;
- 7.9 tons are in solid waste, which DOE plans to dispose at the Waste Isolation Pilot Project (WIPP) a geological repository in New Mexico for transuranic wastes. About half is already emplaced; and
- 2.1 tons are in solid and liquid wastes buried in soil prior to 1970 or held up in facilities at several DOE sites. The DOE considers most of this plutonium to be permanently disposed.

The dramatic increase from the DOE's 1996 waste estimate appears to be due to: reclassification as waste of process residues originally set aside for plutonium recovery for weapons; underestimates of production losses; and improvements in waste characterization data.

The amounted of discarded plutonium also increases the estimate of the total amount of plutonium produced by the U.S. Government from about 0.4 to 3 tons. It's possible that inventory at other sites may have also been reclassified as waste at other sites, which may also explain the increase. If so this would be more compatible with the plutonium production equation used by DOE. There remain uncertainties over how much plutonium was produced and disposed because of gaps in record keeping during the first 25 years of weapons production. DOE should update its Nuclear Materials Management and Safeguards System to take into account recent radioactive waste characterization data.

The Hanford site in Washington State is responsible for nearly a third of DOE's plutonium wastes (4 tons) – more than any site in the U.S. nuclear weapons complex. Despite evidence of significant deep subsurface migration, DOE currently plans to leave about 0.7 MT of plutonium disposed before 1970 behind in the ground at the conclusion of its environmental cleanup at Hanford. DOE should, however, remove as much buried plutonium as possible at Hanford for geologic disposal, as it is doing at the Idaho National Laboratory.

Finally, WIPP is the world's first operating deep geological disposal site for waste that includes significant quantities of weapon-usable material. DOE requires the plutonium-239 content of

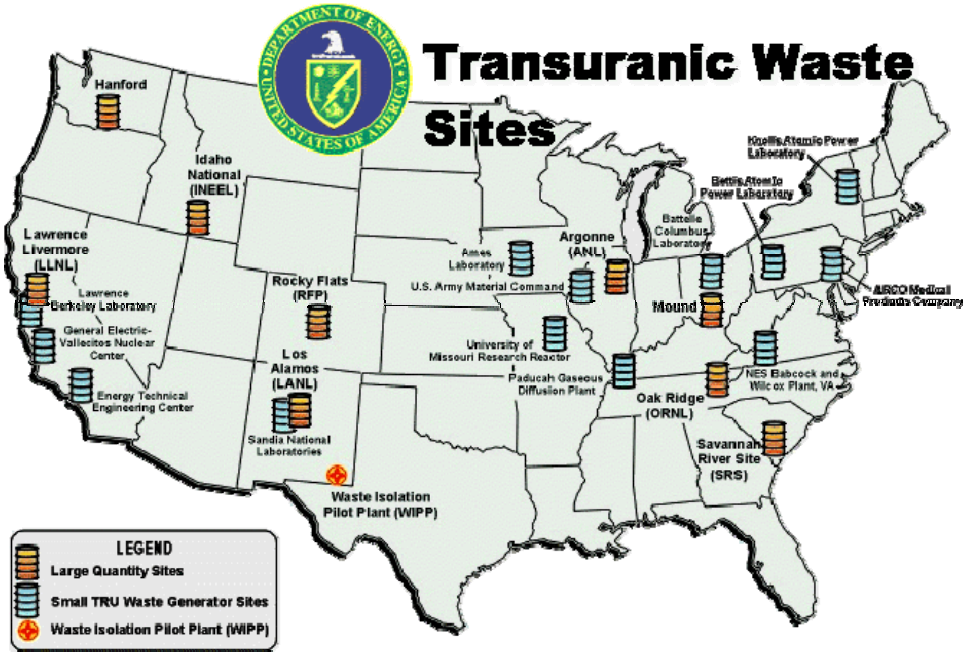
each waste container to be measured. WIPP therefore could be brought under IAEA monitoring prior to its closure, currently planned for 2030. This would be seen internationally as an indication of strengthened U.S. commitment to nuclear disarmament and the Nuclear Non-Proliferation Treaty.

This paper does not address about 7.6 tons of plutonium contained in DOE spent reactor fuel, and 61.5 tons of plutonium declared excess for weapons purposes with the exception of 3.5 tons discarded at the Rocky Flats Plant which is included in the 61.5 tons "excess" declaration. About 41.8 metric tons of the U.S. excess plutonium is expected to be processed so it can be mixed with uranium for fabrication into mixed oxide fuel for use in commercial nuclear power plants and subsequently disposed. Disposition options for 5 tons of "non-pit" plutonium include mixing with defense high-level wastes to be vitrified or direct disposal in WIPP. More plutonium may be declared excess as a result of the 2010 Russia-U.S. strategic arms reduction agreement.[1]

Introduction

The production and fabrication of plutonium primarily for nuclear weapons generated a class of wastes known as transuranics that are contaminated with radioactive elements heavier than uranium on the periodic chart (i.e. plutonium, americium, curium and neptunium). Transuranic Waste (TRU) waste is defined by the U.S. Environmental Protection Agency (40 CFR 91) as having a concentration greater than 100 nanocuries per gram of alpha-emitting transuranic isotopes with half-lives greater than twenty years. There are 21 DOE sites that generated TRU wastes (Figure1).

Figure 1



[1] Treaty Between the United States of America and the Russian Federation on Measures For The Further Reduction And Limitation Of Strategic Nuclear Arms, April 8, 2010. http://www.state.gov/documents/organization/140035.pdf

Plutonium-239 is of greatest concern because of its higher concentration and long half-life of 24,100 years. With a specific activity about 200,000 times greater than uranium, plutonium-239 emits alpha particles as its principal form of radiation. Over time, americium-241 a decay product of 14-year-half life Pu-241, builds up and increases the hazardous external penetrating gamma-ray radiation from transuranic waste.

Alpha particles lose energy quickly within living tissue and create a dense trail of broken molecules. Particles less than a few microns in diameter can penetrate deep in the lungs and lymph nodes, and can also be deposited from the bloodstream in the liver, bone surface and other organs. High doses from inhalation of transuranics can cause lung damage, fibrosis and even death. Tens of micrograms if inhaled can lead to cancer.[2] Over the past several years, a significantly higher incidence of cancer has been reported among workers following exposure to plutonium. [3]

The behavior of plutonium in the environment depends upon its chemical form. It has been found to migrate at greater distances than assumed. [4] As noted by S.S. Hecker, former Director of Los Alamos National Laboratory, it is "one of the most challenging applications of modern chemistry because of the inherent complexity of plutonium and the corresponding complexity of the natural environment."[5]

Prior to the early 1970's TRU wastes were disposed as low-level radioactive wastes directly into the ground. However, due to the hazards of plutonium in particular, the Atomic Energy Commission (DOE's predecessor) decided in 1970 to require disposal of these wastes in a geologic repository designed to contain wastes for at least 10,000 years. Since 1970, TRU wastes have been placed in retrievable containers to allow for deep disposal. The U.S. Congress authorized the design and construction of the Waste Isolation Pilot Project (WIPP) near Carlsbad, New Mexico in 1980 (P.L. 96-164) to dispose of TRU waste generated for military purposes. The bedded salt formations at WIPP were chosen because of their long-term stability and self-sealing properties. The WIPP facility is located 660 meters underground and has an authorized disposal capacity of 175,000 cubic meters. According to recent waste characterization data DOE estimates that 83,050 cubic meters of TRU wastes containing 7.9 tons of plutonium 239 are planned for disposal at WIPP.[6] About half of this plutonium has already been emplaced.[7]

---

[2] National Research Council, *Management and Disposition of Excess Plutonium*, p. 333, National Academy Press, 1995. http://www.nap.edu/catalog.php?record_id=2345#toc

[3] Agency for Toxic Disease Registry, Department of Health and Human Services, Toxicological Profile for Plutonium, September 2007. http://www.atsdr.cdc.gov/tfacts143.pdf

[4] A. B. Kerstin, D. W. Feud, D. L. Finnegan, D. J. Rook, D. K. Smith & J. L. Thompson, "Migration of plutonium in ground water at the Nevada Test Site," *Nature* 397, 56-59 (7 January 1999) http://www.nature.com/nature/journal/v397/n6714/abs/397056a0.html

[5] S.S. Hecker, "Plutonium Science Challenges Future Researchers," *Actinide Research Quarterly*, 2n/3rd Quarter, 2000. http://www.lanl.gov/source/orgs/nmt/nmtdo/AQarchive/00fall/editorial.html

[6] U.S. Department of Energy, *Annual Transuranic Waste Inventory Report-2009*, DOE/TRU-09-3425 Rev. 0. http://www.wipp.energy.gov/library/Baseline2004/FY2009/Annual_TRU_Waste_Inventory_Report-2009_DOE_TRU-2009-3425.pdf

[7] Ibid.

Accounting for Plutonium

Between 1944 and 1994, the DOE estimated that the United States produced and acquired an estimated total of 111.4 tons of plutonium. About 93.5 percent came from government production reactors and the rest from foreign sources and U.S. commercial reactors.[8] DOE accounts for plutonium by reconciling the amount in the "actual" inventory set aside for government requirements and "removals" including material expended in war, weapons testing, transmutation, inventory discrepancies, and waste losses.

In its last official estimate in 1996, DOE reported total amount of plutonium "removed" and no longer available for use was 12 tons, including 3.4 tons lost to waste with an "inventory difference" of 2.8 tons between the book inventory based on the DOE's records and estimates of production, acquisitions and removals compared to the measured quantity in the physical inventory.[9]

Based on more recent waste characterization data (see bibliography), approximately 12.7 tons, more than 11 percent of the total amount of Pu-239 produced and acquired has gone into waste streams (Table 2). Five DOE sites are responsible for about ninety-nine percent of these wastes (Figure 2 and Table 2). The large increase in the estimated amount of plutonium in wastes appears to be due to reclassification of production residues, underestimates of production losses, and better waste characterization.

Reclassification. During the Cold War residual plutonium from production processes were stored and recovered if this was less costly than making new plutonium in production reactors. With the end of nuclear-weapon production, DOE no longer needed these residues and reclassified them as waste. About 3.5 tons of plutonium in residues at DOE's Rocky Flats plant was disposed at WIPP.[10] [11] [12]

Underestimates. Environmental compliance agreements led to more rigorous characterization of waste streams, which found understated waste losses. For instance, because of refinements in waste characterization, the inventory of plutonium in Hanford high-level radioactive waste tanks is more than double the amount estimated in 1996.[13]

There also may be errors in waste data, due to inadequate record-keeping for plutonium discarded prior to 1970. During the first 25 years, when most of the plutonium production occurred, DOE did not have a well-established mass balance system, based on predictive reactor codes allowing for accurate estimates of production; and its material measurement technologies "were less accurate than today."[14]

---

[8] U.S. Department of Energy, *Plutonium: The First 50 years*, DOE/DP-0137, February 1996. http://www.doeal.gov/SWEIS/DOEDocuments/004%20DOE-DP-0137%20Plutonium%2050%20Years.pdf

[9] Ibid.

[10] U.S. Department of Energy, Record of Decision on Management of Certain Plutonium Residues and Scrub Alloy Stored at the Rocky Flats Environmental Technology Site, Federal Register / Vol. 63, No. 230, December 1, 1998.

[11] U.S. Department of Energy, Supplement Analysis for the Disposal of Certain Rocky Flats Plutonium-Bearing Materials at the Waste Isolation Pilot Plant, DOE/EIS-0026-SA-3, November 2002. http://www.wipp.energy.gov/Documents_All_Title.htm

[12] U.S. Department of Energy, Management of Certain Plutonium Residues and Scrub Alloy Stored at the Rocky Flats Environmental Technology Site, Federal Register /Vol. 66, No. 12 /Thursday, January 18, 2001., http://nepa.energy.gov/nepa_documents/rods/2001/4803.pdf

[13] TWINS-2003

[14] DOE/DP-0137, p.53.

According to a 2001 study of nuclear material flow and accounting at Hanford: "The quantities of NM [nuclear material] removed from the inventory as NOL [normal operating losses] do not agree with the quantities of NM classified as waste in the waste management inventory of waste...Significantly more NM was produced in the reactors but not recovered in the separation facilities and was discharged along with fission waste."[15]

DOE is responsible for the Nuclear Materials Management and Safeguards System (NMMSS), which is "the U.S. government's information system containing current and historic data on the possession, use, and shipment of nuclear materials."[16] This revised estimate of discarded plutonium adds about 3 tons to DOE's 1996 estimate of the total amount produced (Table 1).

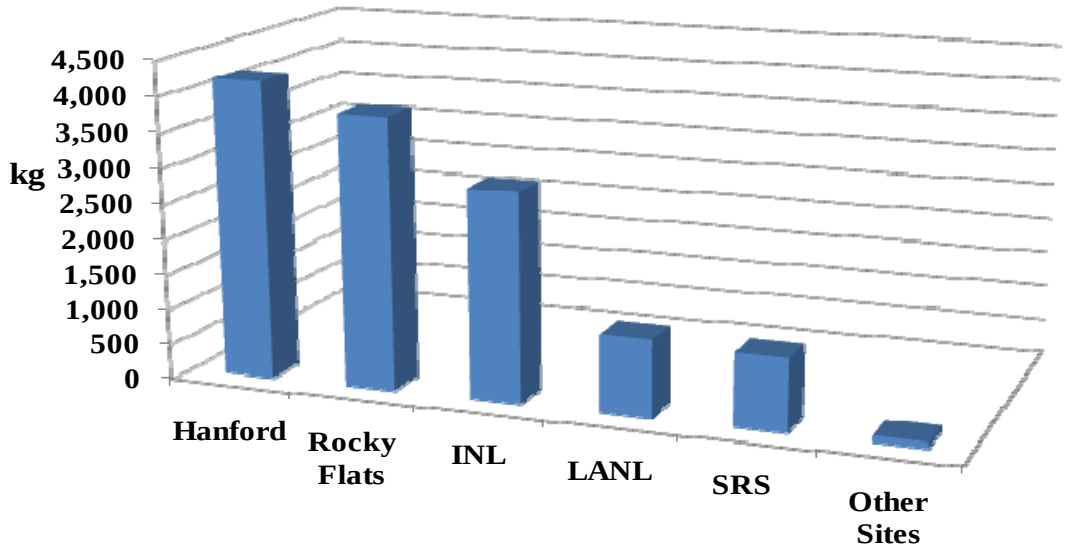
Table 1

	Waste Data (MT)
	12.7
	- 3.9 Normal Operating Losses (DOE 1996)
	-3.5 Reclassification (Rocky Flats)
	- 2.8 Inventory Difference (DOE 1996)
Total	2.5 MT

[15] HNF-8069, p-3-7.

[16] U.S. Department of Energy, Nuclear Materials Management and Safeguards System, User Guide, Release 1.0, Version 1, October 2008. http://www.hss.energy.gov/nmmss/NMMSS%20User%20Guide%20-%20Final%20Version%20dtd%20October%202008.pdf

Figure 1. Plutonium-239 in Wastes at DOE Sites



It appears however, that recent radiological waste characterization data has not been incorporated in NNMMS system because data on plutonium in material declared to be waste is not updated. This creates significant accountability problems at both the national and international levels. DOE should update its 1996 declaration to reconcile waste data. This would reduce uncertainties in historical plutonium production, and provide additional quality assurance for waste data.

Table 2 Plutonium in Waste Inventory (kg)

Site	Description	DOE-Plutonium: The First 50 years (a)	DOE Waste Data
Rocky Flats	Solid Waste (emplaced in WIPP)	47	3,783 (b)
Hanford	High-Level Radioactive Waste	455	1,115(c)
Hanford	Solid Waste (WIPP Bound)	875	1,965 (b)
Hanford	Buried solid Waste		472 (d) (e)
Hanford	Buried Liquid Waste	192	205 (e)
Hanford	Liquid Waste in facilities and holding tanks	--	264 (e)
Los Alamos National Laboratory (LANL)	Solid Waste (WIPP Bound)	610	791 (b)
LANL	Buried Waste	---	50 (f) (6)
Idaho National Laboratory(INL)	Solid Wastes (WIPP Bound)	1,106	1,062 (b)
INL	Pre-1970 Solid Waste (WIPP Bound)	--	1,078(h)
INL	Calcined High-Level Radioactive Waste	72	771 (i)
INL	Solutions Stored in Tank Farms	8	8 (a)
Savannah River Site (SRS)	High-level Radioactive Waste	575	847 (i)
SRS	Solid Waste(WIPP Bound)	193	193 (b)
SRS	Buried Waste	--	25 (k)
Other DOE Sites	Solid Waste(WIPP Bound)	59	82 (b)
Other DOE Sites	Buried Waste	--	27 (l) (m) (n)
TOTAL		**3,919**	**12,737**

(a).DOE/DP-0137(1996),(b) DOE/TRU-09-3425 (2009),(c) TWINS (2003), (d) WHC-SD-WM-ES-325 (1995), (e).PNNL-11800 (1998), (e) DOE/EIS-0391(2009) (f) DOE/EM-00-0384 (2000) (g)DOE-EM- Memo 1994, (h) IC P/EXT-04-00253(2004) (i) DOE/EIS-0287(2002), (j) SRS HLW (1999) (k) WSRC-97-00127 Rev.. 14. (l) ORNLRM- 13487, (m) LA-UR-99-639 (n) DOE/NV/25946-47

Discarded Plutonium at Hanford. The Hanford Engineering Works was one of the world's largest plutonium production centers. Uranium metal fuel, using either natural (0.71wt% U-235) or low-enriched uranium (primarily 0.95 or 1.25wt % U-235) was clad with aluminum to make Spent reactor fuel was discharged into basins of water to allow for cooling and decay of short-lived radionuclides before being sent for chemical separation of plutonium and uranium. Irradiated fuel ruptures and corrosion led to residual plutonium in storage basins and contamination of the nearby environment.[17] [18]

[17] G. B. Malinger C. H. Deluged, M. A. Gerber, B. N. Nat, A. J. Schmidt T. L. Walton, Disposition Options for Hanford Site K-Basin Spent Nuclear Fuel Sludge, PNNL-14729, January 2004. http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14729.pdf

Plutonium was extracted from 98,892 MTU (metric tons uranium) of spent fuel[19] using four chemical separations plants.[20] [21] Additional amounts of plutonium came from offsite sources from other processing facilities and foreign providers.[22] About 70 percent of the irradiated fuel was processed at the PUREX facility, which operated from 1956 to 1972 and 1981 to 1989.[23] After chemical separation, liquid reprocessing waste containing residual amounts of plutonium and other transuranics were mostly transferred to high-level radioactive waste tanks.[24] Plutonium containing liquid wastes was also discharged into cribs, trenches and ponds.[25]

Beginning in 1949, separated plutonium nitrate from the reprocessing plants was sent to the Hanford Plutonium Finishing Plant (PFP), where plutonium was purified into metal and oxides.[26] PFP had several waste streams including gaseous effluents that were filtered and exhausted. Liquid wastes were discharged into unlined soil disposal sites until 1973, when they were sent via a transfer line to high-level waste tanks (see Figures 2 and 3).[27] About 86 percent of Hanford's liquid plutonium waste discharges occurred in the PFP zone.[28]

According to DOE's 1996 official estimate, about 2 percent of the total plutonium produced at Hanford went into waste streams (1.35 tons). [29] More recent waste characterization data indicates about six percent of the plutonium produced at Hanford went into waste streams (4 tons) – nearly one third of all DOE's plutonium wastes and more than any other DOE site.

Of this amount, about 2.7 tons of plutonium in liquid and solid wastes were mostly discharged, or buried in soil. About 264 kg are held up in laboratories, reprocessing plants and holding tanks. An additional 1.1 tons of residual plutonium -- mostly from reprocessing plants -- were discharged into the high-level radioactive waste tanks.[30] The department plans to remove and convert plutonium mixed with high-level radioactive wastes into glass logs for geological disposal.

About 2 tons of buried plutonium is planned for disposal in WIPP. [31] About 0.7 tons were buried prior to 1970. [32] [33] [34]

---

[18] P.C. Jerman, W.N. Koop, F. E Owen, Release of Radioactivity to the Columbia River from Irradiated Fuel Element Ruptures, Hanford Atomics Production Operation, RL-REA-2160, May 1965. http://www5.hanford.gov/ddrs/common/findpage.cfm?AKey=D9042989

[19] U.S. Department of Energy, "Nuclear Material Mass Flow and accountability on the Hanford Site, HNF-8069, October 2001. http://www5.hanford.gov/pdwdocs/fsd0001/osti/2001/I0035319.pdf

[20] They include: the T-Plant and B Plant using Bismuth Phosphate (BiP04) Process (1944–1956), the REDOX facility (1952–1967); and (3) the PUREX plant (1956–1972, 1983–1990

[21] Lesser amounts of nuclear materials such as tritium, neptunium-237, plutonium-238, americium-241 and uranium-233 were also produced at Hanford.

[22] DOE/DP-0137

[23] Separation of plutonium at PUREX was halted in 1972, restarted in 1982, and permanently ended in 1989.

[24] HNF-8069.

[25] Ibid.

[26] HNF-8069, P. 4-5 "The primary chemicals were nitric acid, sodium hydroxide, carbon tetrachloride, aluminum nitrate, tri-butyl phosphate, and calcium, and a number of lesser chemicals also were used."

[27] R.A.Corbin, B.C. Simpson, M.J. Anderson, W.F Danielson III, , J.G. Field,, T.E. Jones, C.T. Kinkaid, Hanford Soil Inventory Model, Rev. 0, PNNL-15367 September 2005

45 SIM, PFP Zone, 2005.

[29] DOE/DP-0137

[30] TWINS 2003

[31] RHO-LD-114, PNNL-11800

[32] DOE/EIS-039, October, 2009, Appendix S,

Figure 2. Plutonium Production at Hanford

Source: HNF-8069 (2001)

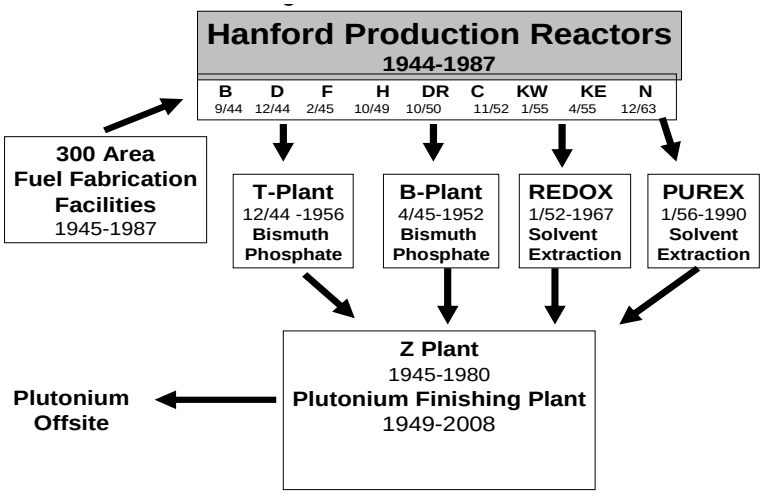
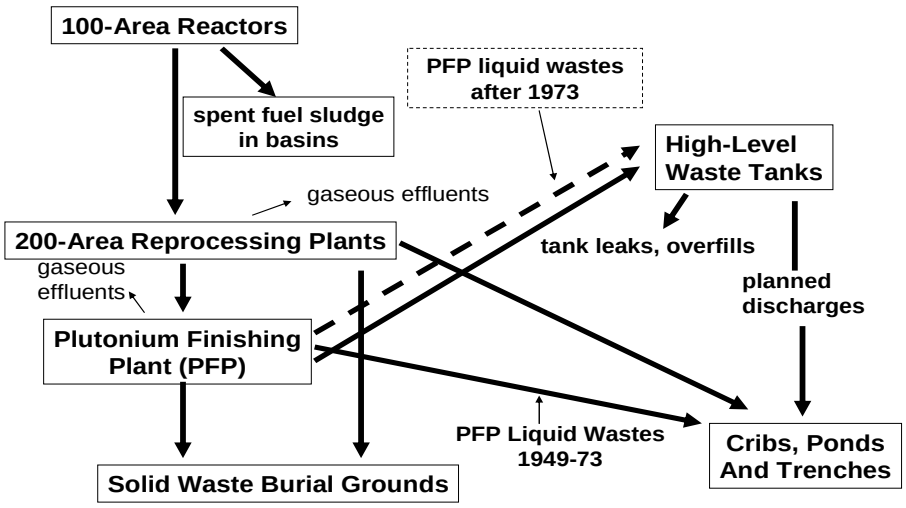


Figure 3. Plutonium Waste Streams at Hanford

Source: HNF-8069 (2001)



Prior to 1970, approximately, about 371 kilograms of plutonium in solid wastes were dumped in containers such as cardboard boxes into unlined trenches mostly associated with the PFP.[35] Between the mid 1960's and 1980, 100 kg plutonium was disposed in a similar fashion in a commercial radioactive waste landfill located in the Hanford 200-East area.[36] More than 60

---

[33] K.R. Ridgeway, M.D. Veatch, D.T. Crawley, Victor I. Sviridov 216-Z-9 History and Safety Analysis, ARH-2207, November 1971. http://www5.hanford.gov/ddrs/common/findpage.cfm?AKey=D8639356

[34] WHC-SD-WM-ES-325

[35] ibid.

[36] PNNL-11800.

percent of the total estimated volume (138,000 cubic meters) of pre-1970 TRU wastes at DOE sites is buried at Hanford.[37]

Production records at Hanford appear to understate plutonium losses. “The ability to measure the plutonium content of waste streams was vastly inferior compared to the ability to measure plutonium in the primary feed and product streams”, researchers concluded in 2001.[38]

A case in point is 216-Z-9 Crib, a soil disposal site roughly the size of a volleyball court (10 m by 20 meters). It operated from July 1955 to June 1962 and received approximately one million gallons (4.6 million liters) of organic and aqueous plutonium discharges from the Hanford RECUPLEX facility -- a scrap recovery operation in the PFP zone. During its operation, this facility processed about 8.7 tons of plutonium. [39] (The plant was closed after a criticality accident in April 1962 that resulted in high exposures to workers.[40]) Although processing records indicated that approximately 27 kilograms were discarded into the crib, samples taken in the years following its closure indicated that the site may have contained as much as 150 kg of plutonium, with a soil concentration as high as 34.5 grams per liter.[41] This was enough so that water intrusion could possibly have set off a nuclear criticality event that could have resulted in near lethal doses to workers.[42] By the late 1970s, 58 kilograms of plutonium had been removed from the top 30 centimeters of soil using remote equipment. [43]

Leaving Buried Plutonium Behind. According to the Government Accountability Office, “DOE has long considered pre-1970s buried wastes permanently disposed.” [44] At Hanford, DOE plans to complete cleanup of about 4 percent of the total acreage containing buried plutonium by 2025 at an estimated cost of $320 million.[45] This cleanup could result in the shallow land disposal of about 0.7 tons of plutonium wastes generated prior to 1970. DOE officials view long-term stewardship efforts, which are likely to rely heavily on land control, site surveillance, monitoring, maintenance, record keeping, and related activities, as inherently low cost. Federal institutional controls, however, require that disposal of radioactive wastes at DOE sites must pose less than a 1 in 10,000 chance of exceeding EPA drinking water standards over a 10,000 year time frame.[46]

---

[37] U.S. Department of Energy, Office of Environmental Management, Summary Data on the Radioactive Waste, Spent Nuclear Fuel, and Contaminated Media Managed by the U.S. Department of Energy, 2000, Chapter 7.
[38] HNF-8069, p. 4-6.
[39] ARH-2207
[40] T P. McLaughlin, S. P. Monahan, N.L. Pruvost, V. V. Frolov, B. G. Ryazanov, A Review of Criticality Accidents, Los Alamos National Laboratory, LA-13638, May 2000. http://www.orau.org/ptp/Library/accidents/la-13638.pdf
[41] ARH-2207, p. 27. “During the seven years of operation, the Recuplex process had an overall Material Unaccounted For (MUF) of 174 kg (about a 2 percent waste loss) and 80 kg across the solvent extraction system. Therefore, it might be assumed the other half of the overall MUF went to solid waste burial.”
[42] Ibid
54., HNF-34075.
http://www.osti.gov/bridge/purl.cover.jsp;jsessionid=ABE18752ADC293B33CDE1204A22AD8E3?purl=/908812-OJpjiK/
[44] United States Government Accountability Office, Report to the Subcommittee on Energy and Water Development, Committee on Appropriations, House of Representatives, Nuclear Waste, Plans for Addressing Most Buried Transuranic Wastes Are Not Final, and Preliminary Cost Estimates Will Likely Increase, GAO-07-761, June 2007. http://www.gao.gov/new.items/d07761.pdf
[45] Ibid.
[46] U.S. Department of Energy, Nuclear Regulatory Commission and Environmental Protection Agency, The Interagency Steering Committee on Radiation Standards Federal Institutional Control Requirements for Radioactive

In 2000, the National Academy of Science challenged the DOE's approach and concluded that: **"Institutional controls will fail [emphasis added].** Past experience with such measures suggests, however, that failures are likely to occur, possibly in the near term, and that humans and environmental resources will be put at risk as a result. "[47]

A recent estimate by the DOE underscores the Academy's concern and finds that plutonium in groundwater from dump sites at Hanford could reach the near shore of the Columbia River in less than 1,000 years at concentrations 283 times greater than the federal drinking water standard. [48]

Currently, based on borehole measurements, plutonium vadose zone contamination at Hanford is relatively uniform with depth and exceeds the 100 nCi/g limit required for removal and geological disposal at depths greater than 100 feet (30 meters). Deep vadose zone contamination at Hanford appears to be orders of magnitude greater than at DOE's Idaho site, which has a greater concentration of buried TRU wastes.[49] [50] (Figure3). Migration beneath Hanford disposal sites has been enhanced by solvents, acids and concentrated salts.[51] Moreover, plutonium has migrated to groundwater beneath the Hanford site.[52]

Data on how readily plutonium sorbs to the surface of soil particles (the partition coefficient or Kd value) is an essential element in understanding its long-term migration. The higher the Kd value the more readily plutonium is held up. [53] DOE's site model uses a Kd value of 150 even though most of the Kd values measured at Hanford are below 10. [54] The model also does not account for the different chemical states of plutonium in the soil, lateral movement and more rapid movement of contaminants that enter into sedimentary cracks, as has been documented at Hanford plutonium waste disposal sites.[55]

Because of environmental compliance requirements at the Idaho National Laboratory, DOE is beginning to remove pre-1970 TRU wastes for geologic disposal. INL is estimated to have about 1.1 tons [56] of plutonium-239 buried before 1970.[57] Beginning in 1954, plutonium-contaminated

---

Waste and Restricted Release of Property Containing Radioactive Material, http://www.hss.energy.gov/nuclearsafety/env/guidance/aea/radtabls.pdf

[47] Committee on Remediation of Buried and Tanks Wastes, Board on Radioactive Waste Management, National Research Council, Long-Term Institutional Management of U.S. Department of Energy Legacy Waste Sites, National Academy Press, (2000). http://www.nap.edu/catalog.php?record_id=9949#toc

[48] DOE/EIS-0391, Appendix U, Table U-2. http://www.hanford.gov/orp/uploadfiles/EIS-0391_D-AppendixU.pdf

[49] U.S. Department of Energy, Idaho National Engineering Laboratory, Dames and Moore, Compilation and Summarization of the Subsurface Disposal Area Radionuclide Transport Data at the Radioactive Waste Management Complex, EGG-ER-10546, Rev. 3, March 1994. http://ar.inel.gov/owa/getgif_2?F_DOC=EGG-ER-10546&F_REV=03&F_PAGE=1&F_GOTO=1

[50] U.S. Department of Energy, Office of Environmental Management, Stoller Hanford Co, Borehole logging reports, DOE-EM/GJ922-2005, 2005.

[51] Ibid.

[52] U.S. Department of Energy, Remedial Investigation Report for the Plutonium/Organic Rich Process Waste Condensate/ Process Waste Group, DOE-RL-2007-27, October 2007. http://www5.hanford.gov/arpir/?content=findpage&AKey=DA05808255

[53] K.J. Cantrell, R.J. Serne, G.V. Last, Hanford Contaminant Distribution Coefficient Database and Users Guide, PNNL-13895 Rev. 1, June 2003, Table 8.

[54] DOE/EIS-039, Appendix M, Table M-10, p. M-20.

[55] DOE-EM/GJ922-2005.

[56] IC P/EXT-04-00253

wastes from the DOE's Rocky Flats plant, which made plutonium weapons components, were disposed at INL. After a major fire in August 1969 at Rocky Flats resulted in burial of an unprecedented amount of plutonium-239 in Idaho,[58] the state resisted further disposal and demanded removal of these wastes from the site. Idaho's opposition contributed to DOE's decision to establish the WIPP repository and to require TRU wastes generated after 1970 to be retrievably stored. In 1995, Idaho entered into an agreement with DOE, and the Environmental Protection Agency that required the removal of high-level radioactive wastes, spent reactor fuel and transuranic wastes from the state by 2035. DOE refused to remove transuranic wastes buried at INL prior to 1970 until the Federal District Court in Idaho ruled in favor of the state in July 2008.[59]

No such regulatory requirement has been incorporated in the environmental compliance agreement at Hanford.[60] DOE should be required, as in Idaho, to remove and process buried plutonium disposed prior to 1970 for geological disposal at WIPP. While it may not be possible to remove deep subsurface concentrations, the technology to remove the major preponderance of these wastes from near surface soil was successfully demonstrated at Hanford thirty years ago. There are likely to be larger costs at Hanford because of the need for remote equipment and deep migration of plutonium.

As DOE embarks on its effort to clean up its most contaminated area in the Central Plateau at Hanford, it is becoming clear that plutonium-contaminated waste will pose one of the most serious risks to the human environment for years to come. Even though the costs of removal and disposal of buried plutonium at WIPP are high, the costs of leaving it behind at Hanford may be incalculable.

Figure 4. Subsurface Contamination at the DOEs Hanford and Idaho Sites

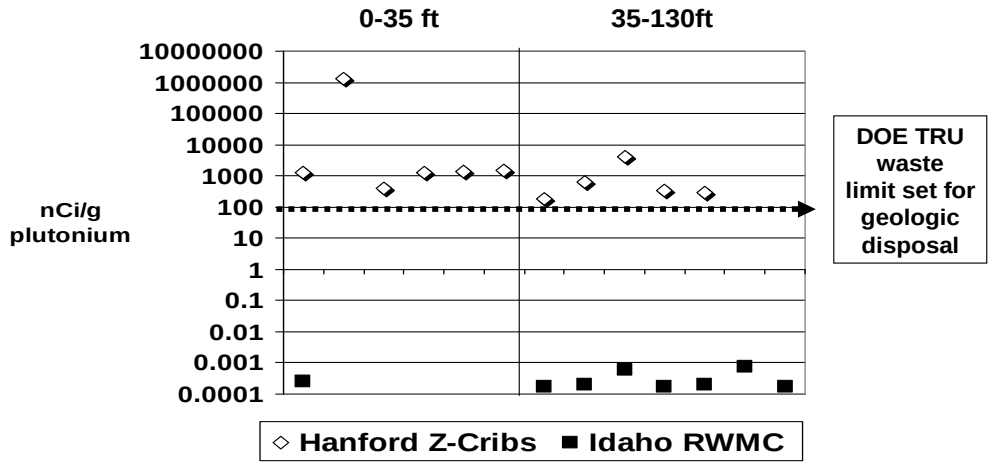
---

[57] DOE/TRU-09-3425, According to this report three waste streams of pre-1970 TRU with a total volume of 8,470 cubic meters containing 4,800 ci/pu-239 and 1080 Ci Pu-240 or 77 kg and 4.6 Kg are currently planned for disposal in WIPP. pp. 144-147

[58] IC P/EXT-04-00253

[59] U.S. District Court for the District of Idaho, Agreement to Implement U.S. District Court Order Dated May, 25, 2006, July 1, 2008.

[60] The Agreement, Hanford Facility Agreement Consent Order by Washington State Department of Ecology, United States Environmental Protection Agency, and the U.S. Department of Energy, As Amended through April 22, 2010. http://www.hanford.gov/?page=81



ɔurces: EGG-ER-10456 Rev. 03
tp://www.hanford.gov/cp/gpp/data/gpl.cfm

International Monitoring

As a weapon state, the United States is not currently obligated to place its nuclear activities under IAEA safeguards. In September 1993, however, President Clinton announced that the United States would place material deemed excess to its defense needs under IAEA safeguards.[61] In 2009, however, the U.S. withdrew 10 tons of HEU that had been subject to IAEA inspection so it could be placed in a new consolidated HEU storage facility that was not designed to allow safeguards on some of its contents.[62] Currently, only about 2 tons of excess plutonium is subject to IAEA safeguards at the DOE's Savannah River Site in South Carolina.[63]

DOE's Waste Acceptance Criteria[64] require that the plutonium-239 content of all TRU waste containers be measured before they can be transported to the WIPP site.[65] All drums undergo non-invasive techniques such as gamma spectroscopy and passive or active neutron measurement. Because of the presence of other hazardous materials, such as volatile organic compounds, additional characterization is required to ensure the safety of the packages. These data are subject to regular audits. The DOE's Waste Acceptance Criteria system for WIPP appears to provide an adequate basis to allow for verification by the International Atomic Energy Agency. This would substantially increase the quantity of excess U.S. defense plutonium under IAEA safeguards, and demonstrate the U.S. commitment to irreversible nuclear arms reductions and set a precedent for international safeguards on other radioactive waste repositories containing significant quantities of plutonium.

---

[61] F. McGoldrick, U.S. Fissile Material Initiatives: Implications for the IAEA, National Reports, IAEA Bulletin, 1995. http://www.iaea.org/Publications/Magazines/Bulletin/Bull371/37104784952.pdf
[62] F. Munger, Knoxville News, No More IAEA Inspections at Y-12, June 7, 2009. http://blogs.knoxnews.com/munger/2009/06/no_more_iaea_inspections_at_y-.html
[63] Ibid.
[64] U.S. Department of Energy, Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant, Rev. 6.4, DOE/WIPP-02-3122, December 2009. www.**wipp**.energy.gov/library/wac/wac.pdf
[65] National Research Council, Board of Radioactive Waste Management, Improving the Characterization Program for Contact-Handled Transuranic Waste Bound for the Waste Isolation Pilot Plant, National Academies Press (2004). http://books.nap.edu/openbook.php?record_id=10900&page=24

Bibliography

T.A. Batcheller, G.D. Redden, Colloidal Plutonium at the OU 7-13/14 Subsurface Disposal Area: Estimate of Inventory and Transport Properties, Bechtel BWTX Idaho LLC, IC P/EXT-04-00253, May 2004, http://ar.inel.gov/images/pdf/200405/2004051900569GSJ.pdf

S.L. Charboneau, J.A.Teal, A.M. Hopkins, C.S. Sutter, Fluor Hanford Co., Decommissioning the 216-Z-Crib Plutonium Mining At the Plutonium Finishing Plant: Issues Characterization, HNF-34075, Rev. 0, June 2007.
http://www.osti.gov/bridge/purl.cover.jsp;jsessionid=ABE18752ADC293B33CDE1204A22AD8E3?purl=/908812-OJpjiK/

J. R. Cochran, B. M. Crowe, F. Di Sanza, Intermediate Depth Burial of Classified Transuranic Wastes, Arid Alluvium, LA-UR-99-639, April 1999.
http://www.osti.gov/energycitations/servlets/purl/334229-5QKgcG/webviewable/

K. R. Conner, Work plan/RCRA Facility Investigation/Remedial Investigation Report for the Old Radioactive Waste Burial Ground 643-E, S01-S22 - Volume I - Text and Volume II – Appendices, WSRC-RP-97-001 27, Rev. 1.4, August 2000. http://sti.srs.gov/fulltext/WSRC-RP-97-00127.pdf

J.M. Crawford, MC&A in a Radiochemical Plant, Westinghouse Savannah River Company, WSRC-MS-98-00752, October 1998 http://sti.srs.gov/fulltext/ms9800752/ms9800752.pdf

M. Fiorvanti, A. Makhijani, Containing the Cold War Mess, Restructuring the Environmental Management of the U.S. Nuclear Weapons Complex, Institute for Energy and Environmental Research, October 1997. http://www.ieer.org/reports/cleanup/ccwm.pdf

W.O. Greenhalgh, Pre-1970 Transuranic Solid Waste at Hanford, Westinghouse Hanford Company, WHC-SD-WM-ES-325, Rev.0, 1995.

M.C. Jacobs, D.L. Uebelacker, Radioactive Contamination in Liquid Wastes Discharged to Ground Within the Chemical Separations Area Control Zone Through 1969, Atlantic Richfield Hanford Co., ARR-1608, March 1970.
http://www5.hanford.gov/ddrs/common/findpage.cfm?AKey=D8603996

C.T. Kincaid et al, Composite Analysis of Low-Level Waste in the 200-Area Plateau of the Hanford Site, PNNL-11800, March 1998.
http://www.pnl.gov/main/publications/external/technical_reports/pnnl-11800-adden-1.pdf

J.D. Leyba, Total Inventory of Selected Radionuclides in Old Solvent Tanks S1 Through S22. WSRC-TR 2000-001, January 2000. http://sti.srs.gov/fulltext/tr2000011/tr2000011.pdf

A.Makhijani., B. Smith, Dangerous Discrepancies: Missing Weapons Plutonium in Los Alamos National Laboratory Waste Accounts, Institute for Energy and Environmental Research, April 2006, Appendix A. http://www.ieer.org/pu/report.pdf

K.W. Owens, Existing Data on the on the 216 Z Liquid Waste Sites, RHO -LD-114, 1981.
http://www5.hanford.gov/arpir/?content=findpage&AKey=D196055124
17 DOE/TRU-2009-3245.

G.Shott, V. Yucel, and L. Desotell, Special Analysis of Transuranic Waste in Trench T04C at the Area 5 Radioactive Waste Management Site, Nevada Test Site, Nye County, Nevada Revision 1.0, DOE/NV/25946—47, May 2008.
http://www.osti.gov/energycitations/servlets/purl/928845-JsyPhq/

R.J. Sloat, Hanford Low Level Waste Management Reevaluation Study, Atlantic Richfield Hanford Company, ARH-231, December 1967.
http://www5.hanford.gov/ddrs/common/findpage.cfm?AKey=D8637403

J.R. Trabalka, Buried Transuranic Wastes at ORNL: Review of Past Estimates and Reconciliation with Current Data, ORNLRM- 13487, September 1997
http://www.osti.gov/energycitations/servlets/purl/661475-uCz5EE/webviewable/

U.S. Department of Energy, Savannah River Site, High-Level Waste Tank Data, Rev. 1, 1999.

U.S. Department of Energy, Summary Data on the Radioactive Waste, Spent Nuclear Fuel, and Contaminated Media Managed by the U.S. Department of Energy, DOE/EM-00-0384 , June 2000. http://www.doeal.gov/SWEIS/DOEDocuments/080%20doe%202000-Buried_TRU.pdf

U.S. Department of Energy, Idaho High-Level Waste and Facilities Disposition, Final Environmental Impact Statement, DOE/EIS-0287, Appendix C-7, Table C.7-3, September 2002.
http://nepa.energy.gov/finalEIS-0287.htm

U.S. Department of Energy, Tank Waste Inventory Network System, Best- Basis Summary Report, (TWINS-2003) September 2003.

U.S. Department of Energy, Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit RI/FS Work Plan: Includes the 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units, DOE/RL-2001-01, Rev.0, April, 2004.
http://www2.hanford.gov/ARPIR/?content=findpage&AKey=D4573392

U.S. Department of Energy, CH2MHILL, Hanford Soil Inventory Model Data (SIM 2005), PFP, WTP-ETF-A-C- Farm, Unassigned 200 Areas 1 and 2, U Plant, T-Plant, T-Farm, S U Farm, Semi-Works, Redox, PUREX, 200E Ponds, 200 W ponds, B-Pant, WM, NRDWL-BC-Control, and PFP zones, 2005.

U.S. Department of Energy, Draft Tank Closure and Waste Management Environmental Impact Statement, for the Hanford Site, Richland, Washington, DOE/EIS-039, October, 2009, Appendix S. http://www.hanford.gov/orp/uploadfiles/EIS-0391_D-Appendix S.pdf