

Potential Disposition Options for Surplus US DOE Nuclear Materials in Support of Disposition Planning

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ABSTRACT

The Disposition Pathway Studies project led by Savannah River National Laboratory and supported by National Nuclear Security Administration's Office of Environment, Safety, and Health, Nuclear Materials Integration Division (NA-ESH-12) seeks to identify potential disposition options for excess DOE materials in support of disposition planning to optimize the safest and most efficient disposition approaches; and progress disposition of those nuclear materials. This paper is focused on recent assessments of nuclear materials in the Department of Energy complex. A subset of the materials consists of bulk plutonium/uranium oxides as well as plutonium/uranium fabricated into unirradiated nuclear fuel components. Due to similar material characteristics between the groups, they have a potential to share common disposition strategies, and some associated challenges are presented that would need to be overcome.

BACKGROUND

The Department of Energy (DOE) has generated substantial quantities of legacy and excess nuclear materials through its weapons production and fuel cycle operations. Significant work has been performed by DOE to address the management and disposition of a large fraction of this nuclear material inventory but there is still a portion of the inventories with indeterminate disposition plans. These materials are identified in each site's end-of-fiscal-year Nuclear Materials Inventory Assessment (NMIA) with a "To Be Determined (TBD)" disposition path.¹ The National Nuclear Security Administration (NNSA) Office of Environment, Safety, and Health (NA-ESH), Nuclear Materials Integration Division (NMID, NA-ESH-12) is leading an effort to identify and advance potential disposition options for those materials including identification of potential beneficial reuse opportunities. In a recent complex-wide nuclear materials review led by Savannah River National Laboratory (SRNL), referred to as the "TBD Study," materials having uncertain disposition pathways were binned into large groupings based on common characteristics.² Potential disposition options were provided for each grouping. The results of this effort supported the DOE assessment of nuclear materials processing and handling infrastructure (NMI) completed in 2021.³

The SRNL TBD Study primarily focused on surplus nuclear materials without an identified disposition pathway. Also identified were nuclear materials that have disposition plans that carry significant risk for success and completion, as well as programmatic materials anticipated to become surplus in the future that will require a disposition capability. As facilities in the DOE complex age and are being deactivated, complex-wide processing capabilities are becoming

limited. Certain facilities and programs have competing priorities that impose constraints on process availability and achievable throughput in support of potential disposition options. Many process capabilities have ceased operating following the end of the cold war.³ In general, disposition of the TBD materials is not always viewed as a high priority. This is often because of their relative stability in interim storage, existing challenges with their disposition, and limited return on investment related to the materials, and other programmatic, regulatory or legal agreements. Furthermore, they are not necessarily co-located with potential processing capabilities which can generate additional challenges to their disposition.

The TBD items and groupings of materials are periodically evaluated by the continuing Disposition Pathway Studies project team and NA-ESH-12 using information contained in the annual NMIA and Nuclear Materials Management Plan (NMMP) submissions prepared by sites and laboratories across the complex in accordance with DOE Order 410.2, Management of Nuclear Materials.¹ Studies are focused on highlighting technically viable potential disposition options for targeted items and the associated challenges that would need to be overcome to advance the effort to execution. This report selectively focuses on groupings that are comprised predominantly of mixed Pu/U material types that have the potential for common disposition pathways.

MIXED PU/U MATERIAL GROUPINGS

A subset of materials in need of disposition planning and execution from across the complex are presented in Table 1. These materials consist of predominantly bulk Pu/U oxides as well as Pu/U oxides fabricated into nuclear fuel components that have never been irradiated.

Table 1. Groupings Containing Mixed Pu/U Materials

Material Location	Category ¹	Name	Material Characteristics
LANL	Dispose	BMUOX/SP100	HEU w/Pu contamination
	TBD	Mixed Material Types & Miscellaneous NDU	Assorted material types, mostly mixed Pu/U materials
	TBD	Assorted MOX Rods	Unirradiated MOX fuel
ORNL	Dispose	"MOX" Rods – 7 Sisters	Unirradiated U/Pu-carbide fuel
SRS	TBD	FFTF Fuel	Hanford Legacy Fuel Assemblies, Pins and Pin Material

Other materials have been evaluated but are awaiting decisions on potential programmatic use. These include Zero Power Physics Reactor and Transient Reactor Test Facility feeds at the Materials and Fuels Complex at Idaho National Laboratory.

POTENTIAL DISPOSITION OPTIONS

A summary of the potential disposition options for the mixed Pu/U groupings in Table 1 are shown in Table 2.² The common disposition options for these materials include H-Canyon processing, vitrification to glass waste and storage pending a future Federal SNF/High-Level Radioactive Waste (HLW) repository; Dilute and Dispose processing and shipment to the Waste Isolation Pilot Plant (WIPP); or direct disposal to WIPP.

Table 2. Potential Disposition Options for Mixed Pu/U Material Types

Mixed Pu/U Material Types		Potential Impact to Federal SNF/HLW Repository			Potential Impact to WIPP/NNSS/Other						
Material Location	Nuclear Material Grouping	Process To Waste With Material Recovery	Process To Waste Without Recovery	Federal SNF/HLW Repository	Direct Disposal	Dilute and Dispose/Downblend	Grouting	Other Process	WIPP	NNSS	Other
LANL	BMUOX/SP100	H-Canyon	H-Canyon	x	LANL	SRS or LANL			x		
LANL	Mixed Material Types & Miscellaneous NDU		H-Canyon	x	LANL	SRS or LANL			x		
LANL	ARIES MOX Rods & Safeguards MOX Rods		H-Canyon	x	LANL	LANL or SRS			x		
ORNL	"MOX" Carbide Rods 7 Sisters		H-Canyon	x	ORNL	ORNL or SRS			x		
SRS	FFTF Fuel		H-Canyon	x	SRS	SRS		Alloying	x		

Disposition via H-Canyon processing is identified as a potential option for all mixed materials listed in Table 2 but this option could become limited as the DOE Office of Environmental Management (DOE-EM) reduces the chemical processing and recovery capabilities in H-Area. An amended record of decision (AROD) for the Accelerated Basin Deinventory (ABD) mission at SRS was issued in 2022. The scope of ABD is focused on H-Canyon processing of SNF currently stored in L-Basin plus limited planned future SNF receipts, and halts the capability for material recovery (i.e., HEU). These materials could potentially be dispositioned through H-Canyon after the assumed ABD mission completion in 2033.⁴ The fuels in Table 2 could be dissolved using an electrolytic or chemical dissolver in H-Canyon. Use of the chemical dissolver would require decladding or size-reduction of the fuel elements and repackaging into a chemical flowsheet-compatible package.² Similarly, processing in the electrolytic dissolver could require size reduction and repackaging depending on the material configuration.

There is potential for disposal of these Pu/U mixed material groupings to WIPP, including the unirradiated fuel, through an approved downblending process. The capability exists for dilution, packaging, and characterization of surplus Pu oxide at SRS for disposition to WIPP. A duplicate downblending capability could also be established and certified at LANL for on-site and off-site materials and, presumably, for disposition of future surplus materials generated from LANL programmatic missions.

For the unirradiated MOX fuels, a capability for disassembly or size-reduction and separation of the mixed oxides from fuel cladding would need to be developed to facilitate downblending or to follow other proposed disposition pathways accessible to the bulk oxides. Direct disposal to a geologic repository is potentially technically viable for some of these materials. For example, for unirradiated MOX fuel containing less than 10 wt% Pu, there is a potential for direct disposal as

Attractiveness Level (ATL) D, precluding the need for downblending operations. In general, evaluation of the technical, legal, and regulatory viability for direct disposal of unirradiated nuclear materials in a deep geologic repository would be needed.

MOX fuel materials like those in FFTF fuel components could also potentially be disassembled and alloyed into a metal waste form (MWF).⁵ The MWF could likely be sent to WIPP for disposition but would require several technical, security, safety and regulatory analyses.

UNITED STATES COMMITMENTS

When reviewing potential disposition options for these mixed Pu-bearing nuclear materials that lack a disposition plan, it is prudent to evaluate preceding United States (U.S.) commitments regarding surplus/excess nuclear materials. Consideration should be given as to whether the materials needing a disposition strategy can be included in current disposition planning efforts to meet these commitments.

A recent report by the National Academy of Sciences (NAS) reviewed the U.S. commitments and material quantities of surplus Pu under consideration or slated for emplacement in WIPP.⁶ Figure 1, reprinted from the NAS report,⁶ shows 48.2 MT from various categories of Pu that are under consideration or slated for disposal at WIPP as diluted surplus Pu transuranic (TRU) waste. Downblending is performed to result in the Pu concentration in the material being below 10 wt % and thus ATL D for disposal to meet criteria for Termination of Safeguards (ToS) or alternative tracking consistent with evolving guidance for Nuclear Materials Control and Accountability.⁷

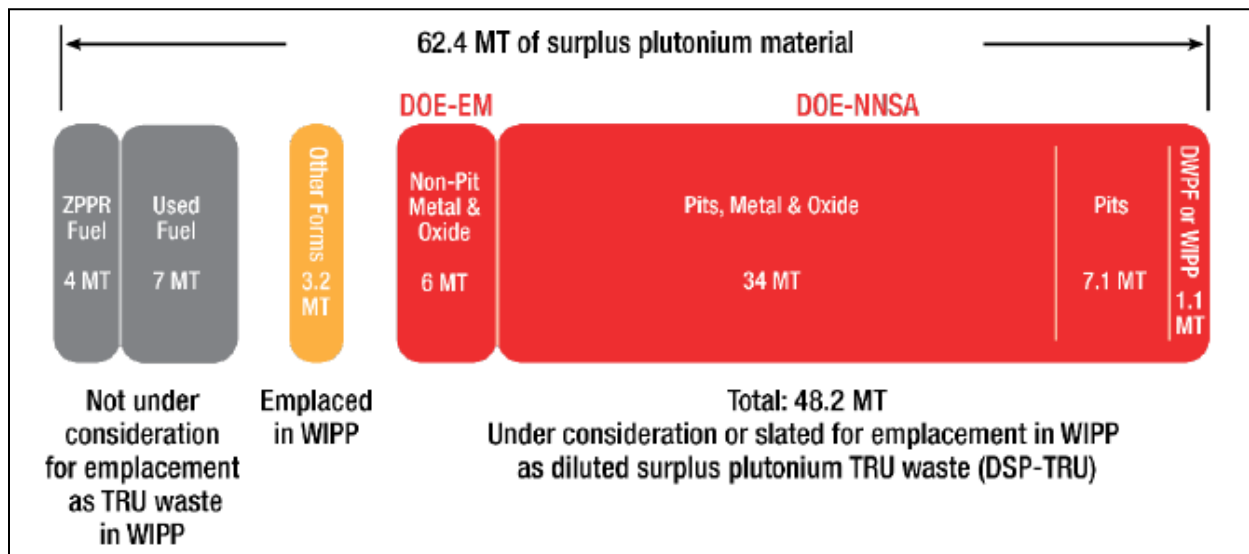


Figure 1. 62.4 MT of U.S. Surplus Plutonium Material for Disposition

The DOE-EM is managing the downblending of non-pit Pu at SRS under a 2016 ROD for the disposition of up to 6 MT of Pu. The program basis for this amount was 5.1 MT surplus Pu plus an additional 0.9 MT Pu from future Gap returns.⁸ The FFTF materials located at SRS are included in the EM “6 MT” of Pu to be dispositioned via direct disposal to WIPP or via downblending at SRS.⁸ The M³ NNSA-managed materials include 34 MT of surplus Pu slated for Dilute and Dispose that was originally to be processed into MOX fuel at SRS to satisfy a U.S.-Russian Pu Management and Disposition Agreement (PMDA);⁹ 7.1 MT of this pit/non-pit Pu is covered under the 2016 ROD⁸ while the remainder of the 34 MT will require future NEPA action. An additional 7.1 MT Pu from future pit designations¹⁰ is not included in either the NNSA (34 MT) or EM “6 MT” disposition programs. An additional 1.1 MT Pu has been, or will be, disposed of at WIPP or processed at the Defense Waste Processing Facility for eventual disposal in a federal high level waste repository.⁶ It is important to note that the earmarked quantities under consideration or slated for disposition to WIPP have not been comprehensively selected at the item level.

CHALLENGES

Some disposition challenges for the materials listed in Table 1 are described below. This section is not intended to be comprehensive but seeks to highlight potential issues to consider in the mixed Pu/U groupings’ disposition planning.

Settlement Agreement to Remove Pu from South Carolina

As part of 2002 legislation, the U.S. Congress required that, in the event the MFFF at SRS failed to achieve its production goals, the DOE would be required to remove plutonium that had been shipped to South Carolina for processing in MFFF that arrived into the state after April 2002 and to pay defined daily fines until it was removed. When the MFFF Project was cancelled by NNSA, South Carolina filed a lawsuit against DOE in 2015 to recoup money from those fines and to require the removal of the Pu from the state. A settlement agreement was reached in August 2020 where if 50 percent or more of the 9.5-MT surplus plutonium inventory brought into South Carolina after 2002 is removed by January 2037, then South Carolina will grant an additional five-year grace period with no legal challenge. NNSA will owe South Carolina a fee based on the fraction of the 9.5-MT inventory remaining in South Carolina as of December 2036.¹¹ Therefore, any future shipments of Pu to SRS would have to be managed in good faith in keeping within the settlement agreement with the state of South Carolina.

Low-Assay Pu Materials

Processing of lower-assay Pu materials would inherently decrease the Pu mass throughput of the process versus high-purity Pu materials; therefore, mixed Pu/U materials may be considered less desirable by the disposition programs if material feed tables are intended to maximize annual Pu processing throughput efficiencies.

Material Characterization by Non-Destructive Assay

More complex measurement standards and/or techniques are needed for mixed Pu/U materials, increasing the difficulty in characterizing these material types. For potential processing,¹² the materials need to be oxidized and stabilized in accordance with DOE-STD-3013 criteria, and analyzed to meet the content envelope requirements of the shipping container to be used for transport, and finally determined to meet the feed specifications for i.e. SRS downblending operations.

Disassembly, Decladding and/or Size-Reduction of Unirradiated MOX Fuel

Disassembly, decladding and/or size reduction of the MOX fuel rods and pellets is necessary to facilitate downblending or to follow any other proposed disposition pathways accessible to the bulk oxides. A disassembly or size reduction capability to accommodate these materials does not currently exist in the DOE complex.

Direct Disposal

Termination or relaxing of safeguards poses a challenge for direct disposal of the ATL C materials to WIPP. Successful completion of activities such as criticality and safety analysis, NEPA analysis, security analyses, and WIPP Performance Assessment evaluation, regulatory applications, and WIPP operations and security control implementation would all be required for this option.

Processing Infrastructure

Processing capabilities in the DOE complex are becoming limited and they also have constraints on availability to support potential mixed Pu/U material disposition options due to higher priority material processing. Processing these mixed Pu/U nuclear materials at DOE facilities (e.g., SRS H-Canyon, K-Area K-Interim Surveillance (KIS) / Surplus Plutonium Disposition (SPD) facility) could extend the facilities planned lifecycles, incurring significant additional costs for lifecycle extensions and associated infrastructure investments.²

CONCLUSIONS

Mixed Pu/U nuclear materials require disposition attention and planning to optimize the safest and most efficient disposition approaches and to progress disposition of those nuclear materials. These DOE-owned materials consist of bulk oxides and Pu/U fabricated into unirradiated nuclear fuel components. Due to similar material characteristics between the groupings, they do have the potential to share common disposition strategies; however, there are associated disposition challenges that would need to be overcome depending on the option selected.

Three mixed Pu/U groupings consist of unirradiated fuel that may require disassembly and the capability to size reduce the Pu/U fuel pellets to facilitate the nuclear material disposition. However, no large-scale disassembly and size-reduction capability exists at the current holding sites - LANL, ORNL and SRS. Efforts to achieve a direct disposal route for the unirradiated MOX fuels, if successful, would preclude the need for fuel disassembly and downblending. Overcoming

challenges associated with regulatory agreements, safeguards and security approaches and other investments made for direct disposal of one group could provide a synergistic disposition benefit regarding similar materials, e.g. stored at other locations, and this approach could result in reduced facility lifecycle impacts.

REFERENCES

1. DOE O 410.2, Management of Nuclear Materials, 2009.
2. P. M. Almond, C. M. Mussi, M. S. Mills, M. J. Aldinger, N. S. Karay, S. M. Peters, J. T. Carter, and W. F. Bates, "Assessment of DOE Nuclear Materials with No Identified Disposition Path," SRNL-RP-2020-00445, August 2020.
3. "Assessment of Nuclear Materials Processing and Handling Infrastructure in the Department of Energy Complex," Final Report Volume 1, US Department of Energy Multi-Program Collaborative Integrated Project Team, June 2021 Update.
4. "Spent Nuclear Fuel Management, Accelerated Basin De-Inventory Mission for H-Canyon, at the Savannah River Site," Amended Record of Decision pursuant to the Savannah River Site Spent Nuclear Fuel Management Final Environmental Impact Statement (DOE/EIS-0279, 2000), 87 FR 23504, April 2022.
5. P. M. Almond, N. S. Karay, M. S. Mills, H. W. Eldridge, M. J. Aldinger, J. T. Carter, S. M. Peters, C. M. Mussi, G. B. Green, and W. F. Bates, "Flowsheet and Disposition Options Development for SRS Nuclear Materials with No Disposition Pathway," SRNL-RP-2021-04695, September 2021.
6. National Academies of Sciences, Engineering, and Medicine 2020. *Review of the Department of Energy's Plans for Disposal of Surplus Plutonium in the Waste Isolation Pilot Plant*. Washington, DC: The National Academies Press.
7. DOE O 474.2A, Nuclear Material Control and Accountability, 2023.
8. Surplus Plutonium Disposition: Record of Decision. Federal Register 81(65):19588-19594, 2016.
9. DOS, 2010. Protocol to the Agreement between the Government of the United States of America and the Government of the Russian Federation Concerning the Management and Disposition of Plutonium Designated as No Longer Required for Defense Purposes and Related Cooperation. 2011-0136. Washington, DC.
10. Surplus Plutonium Disposition Supplemental Environmental Impact Statement. EIS-0283-S2. Washington, DC, 2015.

11. State of South Carolina v. The United States, Settlement Agreement, Fed. Cir. No. 19-2324, 2020.
12. Stabilization, Packaging, and Storage of Plutonium-Bearing Materials, DOE Standard, DOE-STD-3013-2018, November 2018.