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Author(s): Gould, Sarah Catherine

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Transuranic Waste Volume Reduction Methods for Los Alamos National Laboratory

Sarah Gould

Department of Nuclear Engineering, North Carolina State University, Raleigh, NC, 27695, scgould@ncsu.edu
Pollution Prevention Program, Los Alamos National Laboratory, Los Alamos, NM, 87544, sgould@lanl.gov

INTRODUCTION

Los Alamos National Laboratory (LANL, or the Lab) is one of the United States' (U.S.) weapons complex nuclear security laboratories; it is owned by the Department of Energy (DOE) and operated by Triad National Security, LLC [1]. LANL's mission is to solve national security challenges through scientific excellence, which includes nuclear deterrence and stockpile stewardship [2]. Such activities generate a variety of radioactive waste types, including transuranic (TRU) waste.

The National Nuclear Security Administration (NNSA) is under a congressional mandate to produce no fewer than 80 plutonium pits per year by 2030 to meet Department of Defense requirements and support the nuclear deterrent. LANL is responsible for producing at least 30 pits per year by 2026, while the Savannah River Site will produce 50 pits per year by 2030 [3].

As of August 2018, the NNSA TRU waste inventory at LANL was at 53% capacity. In order to ensure the nuclear material missions are able to continue uninterrupted, the storage of TRU waste needs to remain below 60% of total capacity [4]. As LANL increases production and prepares to meet the 30 pits per year goal, waste generation will increase substantially. Thus, there is a need to rejuvenate current infrastructure and implement TRU waste reduction methods in the coming years.

OBJECTIVE

The primary objective of this work was to analyze the composition of TRU waste at LANL in order to identify opportunities for rejuvenating infrastructure within the Plutonium Facility. These opportunities are meant to reduce the volume of TRU waste in preparation for the 30 pits per year requirement.

WASTE GENERATION

A variety of radioactive wastes are generated from the Plutonium Facility at the Lab, including low-level waste (LLW), mixed waste, and TRU waste. LLW is radioactively contaminated waste that is not high-level waste, spent nuclear fuel, TRU waste, byproduct material, or naturally occurring radioactive material [5]. Mixed waste contains both nuclear material and a hazardous component subject to the Resource Conservation and Recovery Act (RCRA) [5]. TRU wastes refer to anthropogenic radioactive elements with an atomic number of 92 or higher, containing greater than 100 nanocuries of alpha-emitting isotopes per gram of waste with half-lives greater than 20 years [5].

The majority of the TRU waste in the United States is from nuclear weapons production facilities, including LANL, and comes from equipment, instruments, personal protective equipment (PPE), and laboratory ware used inside of gloveboxes which is contaminated with anthropogenic radioactive elements [6-7]. All TRU waste must be disposed of in the Waste Isolation Pilot Plant (WIPP), the nation's only deep geological repository for nuclear waste [7].

Waste destined for the WIPP must be in compliance with the WIPP's Waste Acceptance Criteria (WAC) to ensure that it is managed and disposed of in a manner that protects human and environmental health [8]. Acceptable Knowledge (AK) specialists at LANL document waste contents in the Waste Compliance and Tracking System (WCATS) to help ensure compliance with the WIPP WAC [9]. AK specialists fill out a WCATS Questionnaire (WQ) for each waste drum to accurately account for waste contents. WQs provide information about the process which generated the waste as well as matrix contents by volume-percent of a drum. The handwritten WQ for each waste container is scanned and uploaded into the WCATS database as a PDF file.

Matrix and process details from 686 WQs from fiscal year 2020 were recorded and analyzed to identify the top contributors to TRU waste at LANL by volume. Matrices were split into categories based on material type: non-actinide metal ("Metal"), ceramic, plastic, rubber, cellulose, glass, and salt. Matrices composed of either mixed materials or minority materials were counted in the miscellaneous category. Results of this analysis are shown in Figure 1 and identify the two largest contributors to TRU waste from fiscal year 2020 to be non-actinide metal (38%) and plastic (19%).

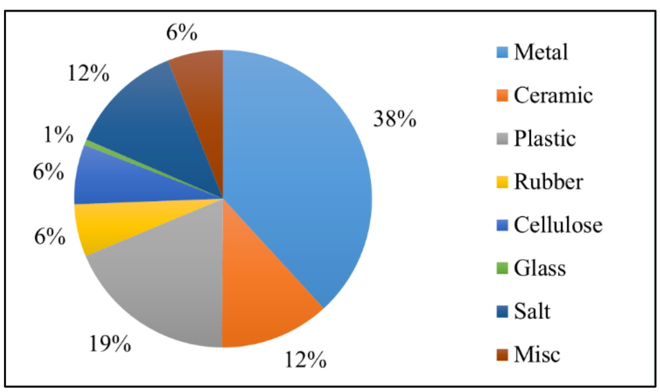

Fig 1. Volume-percent composition of TRU waste from FY2020 by material matrix.

Waste in the category of non-actinide metals includes metallic waste items such as tools, process equipment, and glovebox structures which have been radioactively contaminated with actinides. Waste in the category of plastic includes items such as bag out bags and other plastic bags, vinyl tape, and plastic bottles which have been contaminated with actinides.

The results of a similar analysis on the composition of TRU waste from the Nuclear Materials Technology (NMT) division, the primary waste generator, in 1998 and 1999 revealed that the two major matrices comprising waste were non-actinide metals (35%) and combustible materials (28%) [6], shown in Figure 2.

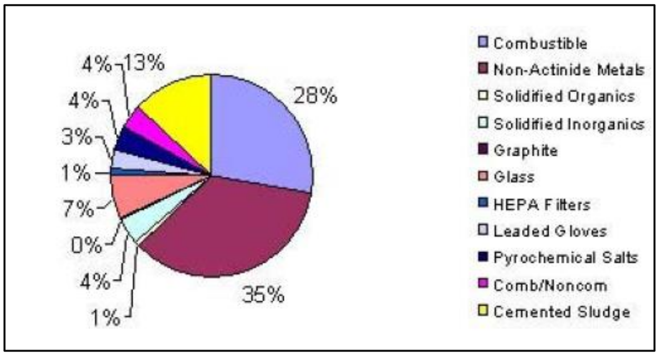

Fig 2. Volume-percent composition of TRU waste from NMT division (FY98 and FY99) by material matrix [6].

For the 1998-1999 analysis, combustible waste included any materials that can be reduced to ash, including plastic, rubber, and cellulosics. As a comparison, the sum of plastic, rubber, and cellulose waste from fiscal year 2020 was ~ 31% of the total volume produced. Thus, the volume-percent composition of both non-actinide metals and combustibles increased from 1998-1999 to 2020; non-actinide metals increased from 35% to 38%, and combustibles increased from 28% to 31% of the total volume. This illustrates the persistence of non-actinide metal and combustibles (particularly plastic) as the largest contributors to TRU waste over time based on volume dominance in the waste streams.

TRU WASTE REDUCTION METHODS

Figure 1 illustrates that the highest-volume contributors to LANL TRU waste in fiscal year 2020 were non-actinide metals (38%) and plastics (19%). Figure 2 illustrates that these waste streams were the largest contributors by volume in 1998-1999 as well, assuming that plastic was also then the majority combustible waste, emphasizing the dominance of these waste streams over time. Waste reduction methods that reduce these two TRU waste streams would therefore have the largest effect on TRU waste reduction.

The most effective method of reducing the volume of waste is to avoid generating it. Thus, waste reduction methods which are source reduction efforts rather than waste treatment efforts should be prioritized. However, in many cases waste generation cannot be avoided due to the nature of the materials and processes. In addition, source reduction methods often take many years to implement when structural change is required, while waste treatment methods have a shorter timeline for implementation.

Because LANL has the goal of increasing production to 30 pits per year by 2026, TRU waste reduction methods need to be explored as soon as possible. Therefore, a combination of source reduction and waste treatment methods will be the most effective solution to reduce the volume of TRU waste in a timeline that supports the 30 pits per year requirement.

Reduction Methods at LANL

LANL has over 75 years of experience in handling radioactive materials and, consequently, in managing radioactive waste. Despite the increasing contributions of non-actinide metals and plastics to the TRU waste stream, many waste reduction efforts in these categories have been explored or implemented.

The SAVY Recovery Process is a source reduction method used at LANL to decrease non-actinide metal TRU waste. SAVY-4000 containers are metal containers made for the storage and transport of solid nuclear materials inside a nuclear facility [10]. These containers were previously discarded as TRU waste, which was both an inefficient use of waste drum volume and an unnecessarily high cost due to the value of SAVY-4000 containers. Within the last five years, a new process was implemented to place waste items in a slip top container and then into a SAVY-4000 container for transportation and storage [11]. During the container recovery process, the slip top is placed in a waste drum and the SAVY-4000 container, which did not come into direct contact with waste, can be made available for reuse. In current waste generation processes, recovery and reuse of SAVY-4000 containers reduces the volume of non-actinide metal TRU waste and is made a priority.

Electrolytic decontamination is a waste treatment method that utilizes a recycled electrolyte solution to etch the metal surfaces of a glovebox via a small electrode fixture, which removes a thin layer of steel and associated contamination [12-13]. The electrolytic solution is then filtered to remove any contamination and can be reused. This method can be used to decontaminate gloveboxes to low levels for further use or characterization as LLW.

A compaction method is used for some plastic TRU waste such as plastic carboy containers. Previously, only two carboy containers were packed into a waste drum, an inefficient use of valuable drum space. Using a compaction method to cut the plastic containers into smaller pieces, programs are now able to fit 10-14 carboys into a waste container [13].

Sort and Segregation is a TRU waste minimization effort which differentiates LLW from TRU waste produced in the Plutonium Facility. Historically, all process waste from this area was considered TRU waste, but the sort and segregation process detects non-mixed waste items with a low initial assay which are then re-assayed to determine if they can be characterized as LLW rather than TRU waste [12]. LLW is a preferred waste characterization compared to TRU waste because it is significantly less expensive to dispose of and poses less hazard to human and environmental health.

Several other waste reduction efforts are being explored, particularly through the TRU Waste Reduction Study Group and the Pollution Prevention (P2) program. Examples include: inventory management to prevent the introduction of unnecessary materials which must be discarded as TRU waste, promoting the procurement of high-quality equipment with higher useable lifetimes than their less expensive counterparts, cerium nitrate decontamination to remove radioactive contamination from gloveboxes, installing in-line equipment that measures radioactivity to reduce handling and exposure and improve LLW segregation, and more [13-15].

Additional Reduction Methods

Although LANL has implemented several TRU waste reduction methods, further improvements are needed to maintain the storage capacity limits to continue production for the 30 pits per year requirement. Several options exist which may be viable to reduce LANL TRU waste for the non-actinide metal and plastic waste streams.

Incineration is a common waste treatment method for reducing the volume of generated plastic wastes in the nuclear industry. Incineration involves the combustion of solid waste at high temperatures, releasing CO_2, H_2O, S, and hydrochloric acid as by-products, and requires gas-filtering systems to control the radioactive discharges [16]. Although incineration has high volume reduction factors, the process produces a secondary waste stream in the form of loaded filters, so this method should not be considered further for reducing plastic TRU waste [17].

Compaction or granulation is another common waste treatment method to reduce the volume of generated plastic wastes. This method is used for compacting and shredding combustible waste streams, such as the plastics ubiquitous in LANL TRU waste, to achieve higher-density packaging [6]. The compaction/granulation technology could yield up to an 80% reduction in waste volume of plastic wastes, which would be a significant improvement in LANL TRU waste reduction [6]. This method has been considered for plastic wastes at LANL in the past but was not implemented, likely due to a lack of glovebox availability in the Plutonium Facility. With programmatic changes and infrastructure rejuvenation occurring at LANL in preparation of the 30 pits per year requirement, this method may have more available options for implementation and should be explored.

Melt densification is a waste treatment method which reduces the volume of radioactively contaminated plastic wastes. With melt densification, plastic waste is melted at temperatures below 200 ℃, which is in the range for industrial plastic recycling [17]. Melting the plastics at a low temperature gives rise to two beneficial properties: the release of radioactivity to the air is not expected because the melting temperature of plastics is very low compared to the melting or boiling points of the radionuclides and the plastic should not lose its structural integrity when melted at such a low temperature, therefore any gas concentrations given off are not expected to exceed permissible levels [16]. Melt densification has a higher volume reduction factor than compaction/granulation and does not produce the secondary waste of incineration; therefore, it may be an attractive TRU waste reduction method for actinide-contaminated plastic at LANL.

Microbial bioremediation utilizes the metabolic activity of microorganisms in the removal and conversion of radioactive compounds to a less radioactive, or even nonradioactive, form [16]. Microbial processes can reduce the toxicity of radioactive elements by two means: direct reduction of radioactive heavy metals by microorganisms or indirect electron transfer by metal-reducing microorganisms to radionuclides [16]. Radionuclide-microbe interactions which have shown reductions in toxicity have been demonstrated with ^{90}Sr, ^{137}Cs, ^{237}Np, and ^{239}Pu, all of which are actinides that produce TRU waste at LANL [16]. However, due to the extensive amount of further research and time required to assess and implement microbial bioremediation at LANL, it would not be beneficial for the 30 pits per year requirement.

CHALLENGES

There are several challenges associated with the implementation of new TRU waste reduction technologies at LANL. The first of these challenges is the availability of gloveboxes and space within the Plutonium Facility because laboratory space is a highly valuable resource at LANL. This problem will only worsen as the Lab prepares to meet the 30 pits per year requirement and more staff are needed in the Plutonium Facility. Thus, installation of new TRU waste reduction efforts must compete for space with programmatic priorities, such as the expanding footprint for the 30 pits per year requirement [6].

Another challenge is the difficulty of obtaining long-term funding to support TRU waste reduction efforts. Often, a project will receive funding from several sources in the early phases but lack the long-term funding commitment required to continue the work through implementation. Furthermore, any new technology or process seeking implementation in the Plutonium Facility must meet rigid safety requirements before approval is authorized, adding to the high cost of implementation [6].

In addition, any TRU waste reduction methods must be implemented within the next few years to ensure the Lab does not exceed storage capacity requirements and can maintain production toward 30 pits per year. This challenge is exacerbated by the lack of glovebox space available in the

Plutonium Facility and the difficulty in establishing a long-term funding source. Thus, many TRU waste reduction efforts which may have been potentially viable solutions may no longer be considered if the timeline for implementation exceeds the 2026 production goal of 30 pits per year.

CONCLUSION

To achieve the highest TRU waste volume reduction, LANL should prioritize waste reduction methods for non-actinide metal and plastic wastes. Although several TRU waste reduction efforts have been implemented, further improvements are needed to rejuvenate infrastructure to prepare for the increased waste production expected from the 30 pits per year requirement. LANL should continue to pursue any in-development waste reduction efforts and explore other novel waste reduction methods.

Source reduction methods should be given higher priority overall because the most effective method of reducing waste is to avoid generating it. However, waste treatment methods are also needed to reduce the volume of TRU waste after necessary production. Waste treatment methods that LANL can implement to reduce the volume of TRU waste to support the 30 pits per year requirement by 2026 must be pursued first. These methods include compaction or granulation and melt densification to decrease plastic TRU wastes. Further methods to reduce the volume of non-actinide metals should also be explored.

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