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Recommendations for Reduction in Radionuclide Analyte Analysis in Support of WTP Operations

April 2019

CE Lonergan

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
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Abstract

In support of direct feed low-activity waste operations for the Hanford Tank Waste Treatment and Immobilization Plant (WTP), this document discusses currently required radionuclide sample analyses in low-activity waste samples, which, if any, are planned to be measured. The key goal being to identify isotopes that may be eliminated from required measurements due to low risk of impact on regulatory compliance or reporting. The total number of sample analyses to be completed during WTP operations is more than 18,000 per year which result in large amounts of secondary waste, opportunities for exposure and significant amounts of time for analysis, especially if delays occur. Often this analytical endeavor can be complicated due to troublesome components. Such components cause issues due to low concentrations, lengthy sample preparation for analysis, (e.g., elemental separations, lack of standards) or other reasons. This assessment seeks to provide justification to remove onerous or troublesome components that are present in low enough concentrations to not pose a threat of the resulting waste form being non-compliant if not measured. If it can be demonstrated that the large number of analyses is not needed, it will reduce hold times during processing, decrease the cost of operation, and reduce potential exposure of personnel.

This document provides recommendations for removal of analysis for radionuclides in low-activity waste that may not require analytical determination and can be safely estimated from process knowledge. The analytes recommended for elimination from required analysis were determined via calculations of their concentrations in low-activity waste batch feed estimates from the Tank Utilization Assessment of 2013. A total of 746 batch low-activity waste feed estimates, representing waste compositions throughout the lifetime of the Hanford mission, were analyzed, and radionuclide concentrations were compared against established reporting and contractual limits as specified in the WTP contract and the documents it references. Analytes that were found to be consistently below the limits of NUREG/BR-0204, the WTP contract, or 49 CFR 172.101 (or any combination of these) include many transuranic radionuclides and other radionuclides present in the waste in small concentrations. A total of 22 of the 44 radionuclides in the batch estimates were not significant in any batch feeds.

Summary

The Hanford Tank Waste Treatment and Immobilization Plant (WTP) is currently under construction and, once complete, will start converting the 56 million gallons of waste on the Hanford Site into waste forms. The operations involved in the vitrification of the waste must comply with various requirements and regulations. The entire set of operations is governed by the WTP contract, which specifies what information is required to show compliance or what supporting documents should be referenced to understand what is needed for compliance.[1] Examples of such documents referenced in this work include NUREG/BR-0204,[2] as passed down from the U.S. Nuclear Regulatory Commission, and 49 CFR 172.101.[3] In particular, this report focuses on the assessment of radionuclide concentrations in low-activity waste (LAW) feed estimates forecasted for vitrification operations and the associated requirements set forth to ensure regulatory and reporting compliance.

The current plan is to ensure compliance via routine sampling at different points in the vitrification process.[4,5] The sampling process will include testing the waste before it enters the processing plant as well as in the LAW feed process after treatment for cesium removal, and total analyses can exceed 10,000 measurements. This large number of samples to be analyzed likely will place stress on the analytical facilities, potentially increasing process uncertainties and overall time of plant operation due to hold points. Other negative impacts include generation of large volumes of the radioactive waste and unnecessary worker exposure. To determine if any radionuclide analytes can be removed from the required measurements, LAW feed batches from the Tank Utilization Assessment of 2013 (TUA2013) were analyzed and radionuclide concentrations were calculated and compared with the regulatory and reporting limits referenced in the WTP contract.[6] It should be noted that several isotopes are required for measurement according to the contract and are not recommended for removal which are: ^{99}Tc, ^{137}Cs, and ^{90}Sr.

Calculations using the TUA2013 values for radionuclide concentrations were performed assuming 26 wt% Na_2O loading in the waste. The percentage of batches out of 746 for the full Hanford mission or out of 386 for the first 10 years of the mission that contained significant amounts of the analytes were determined for all analytes. Additionally, concentrations of each isotope relative to its “significant” value or operating limit was shown as a function of batch. “Significant” is defined by the WTP contract and the documents referenced within based on the corresponding limit. Several components deemed challenging for analyses according to the Hanford 222-S Laboratory, including ^{106}Ru, ^{134}Cs, and ^{242}Cm, were found to never reach significant levels in any batches. Other radionuclides were present at significant levels in varying

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[1] WTP Contract, Contract No. DE-AC27-01RV14136 (2000). U.S. Department of Energy, Richland, WA.
[2] DOT (1998). *Instructions for Completing NRC’s Uniform Low-Level Radioactive Waste Manifest*. U.S. Department of Transportation, Washington, D.C., NUREG/BR-0204, Rev. 2.
[3] 49 CFR 172.101 (2017). Purpose and use of hazardous materials table. U.S. Code of Federal Regulations.
[4] Arakali A and J Johnston (2013). *Integrated Sampling and Analysis Plan (ISAP)*. Bechtel National, Inc., Richland, WA, 24590-LAB-PL-OP-12-0001, Rev. 0.
[5] Nguyen DM (2018). *Integrated DFLAW Feed Qualification Data Quality Objectives*. Washington River Protection Solutions, LLC, Richland, WA, RPP-RPT-59494.
[6] Jenkins KD, R Gimpel, and YN Deng (2013). *2013 Tank Utilization Assessment (TUA) Part 1: Potential Impact of Advanced Glass Models on the WTP*. Bechtel National, Inc., Richland, WA, 24590-WTP-RPT-PE-13-003, Rev. 0.

numbers of batches. If the percentage of batches containing a significant level of an analyte was 1% or less, the analyte was considered a candidate for removal from required analysis.

The following analytes (Table S.1) were not found to be significant under any of the above regulations or requirements based on the TUA2013 values for no oxidative, or caustic, leaching estimates with a normalized to Na_2O-loading of 26 wt%. Note that 26 wt% was selected as a conservative (larger than expected) waste loading. Thus, the calculations and the recommendations discussed in this document may be considered conservative, and if conservatism were removed, more analytes could become insignificant due to lower concentrations in the batch estimates.

Table S.1. Analytes determined to not be significant, or exceed their limit, in 1% or less of batches for requirements discussed in this document.

Document Establishing the Limit for the Analytes	Troublesome Analytes[(a)]	Transuranic Analytes	Other Analytes
NUREG/BR-0204; WTP contract; 49 CFR 172.101; any combination of the above	^{106}Ru, ^{134}Cs, ^{242}Cm, ^{59}Ni	^{242}Cm, ^{242}Pu, ^{243}Cm	^{125}Sb, ^{152}Eu, ^{154}Eu, ^{155}Eu, ^{226}Ra, ^{228}Ra, ^{229}Th, ^{232}U, ^{233}U, ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{60}Co, ^{79}Se, ^{93}Nb
NUREG/BR-0204	^{93}Zr, ^{126}Sn, ^{243}Am	^{238}Pu, ^{237}Np, ^{244}Cm, ^{243}Am	^{137m}Ba, ^{129}I, ^{137}Cs, ^{113}Cd, ^{227}Ac, ^{241}Pu, ^{232}Th, ^{231}Pa
49 CFR 172.101	-	-	^{241}Pu, ^{232}Th, ^{231}Pa

(a) Source: Sasaki LM (2018). *Evaluation of Tank 241-AP-107 Direct Feed Low-Activity Waste Pre-Qualification Sampling and Analysis*. Washington River Protection Solutions, LLC, Richland, WA, RPP-RPT-60946, Rev. 00.

The analytes listed in Table S.1 were shown to be below the limits of “significance” when compared to the indicated documentation. The “All Documents” row indicates analytes that will be insignificant based on calculations completed with TUA2013 batch estimates in all cases. This report evaluated the waste delivered to the LAW treatment facilities and does not provide any recommendations for high-level waste streams.

Acknowledgments

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Quality Assurance

This work was performed in accordance with the Pacific Northwest National Laboratory (PNNL) Nuclear Quality Assurance Program (NQAP). The NQAP complies with U.S. Department of Energy (DOE) Order 414.1D, *Quality Assurance*, and 10 CFR 830 Subpart A, *Quality Assurance Requirements*. The NQAP uses NQA 1 2012, *Quality Assurance Requirements for Nuclear Facility Application*, as its consensus standard and NQA-1 2012, Subpart 4.2.1 as the basis for its graded approach to quality.

The NQAP works in conjunction with PNNL's laboratory-level Quality Management Program, which is based on the requirements as defined in DOE Order 414.1D, *Quality Assurance*, and 10 CFR 830, *Nuclear Safety Management*, Subpart A, "Quality Assurance Requirements." The information associated with this report was acquired under a "Basic Research" designation and should not be used as design input or operating parameters without additional qualification.

Acronyms and Abbreviations

CFR	Code of Federal Regulations
DFLAW	direct feed low-activity waste
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
GEA	gamma energy analysis
GFC	glass forming chemical
GPC	gas flow proportional counting
HLW	high-level waste
ICP-MS	inductively coupled plasma mass spectroscopy
ILAW	immobilized low-activity waste
LAW	low-activity waste
NRC	U.S. Nuclear Regulatory Commission
SOF	sum of fractions
TRU	transuranic (radionuclides: ^{237}Np, ^{238}Pu, $^{239/240}Pu$, ^{242}Pu, ^{241}Am, ^{243}Am, ^{242}Cm, $^{243/244}Cm$)
TUA	tank utilization assessment
TUA2013	Tank Utilization Assessment of 2013
U.S.	United States (of America)
WTP	Hanford Tank Waste Treatment and Immobilization Plant

Contents

Figures

Tables

1.0 Introduction

The Hanford Tank Waste Treatment and Immobilization Plant (WTP) facilities are currently under construction and will convert millions of gallons of waste stored in tanks on the Hanford Site into stable waste forms. The will be separated into low-activity waste (LAW) and high-level waste (HLW) fractions. Both fractions will be vitrified, i.e., turned into glass, and will become either an immobilized LAW (ILAW) product or an immobilized HLW (IHLW) glass waste form. This document discusses determination and analysis of radionuclide concentrations during LAW vitrification and does not include any recommendations or suggestions pertaining to HLW processing.

1.1 Background

The waste will be retrieved from the tanks and subjected to treatment, including cesium removal [1]. Once treated, the waste will be moved into mixing vessels and combined with glass forming chemicals (GFCs), followed by transfer to a melter. Throughout the vitrification process, data is to be acquired that demonstrates that the waste and final immobilized product do not exceed any restrictions [1][2]. This effort will occur as part of the feed qualification program, and the current approach for ensuring compliance includes extensive measurement of samples taken from various points in the vitrification process [3]-[4]. Efforts are currently underway to determine the best approaches for implementing real-time in-line monitoring and how that will impact sampling [5]. Additionally, along with in-line monitoring, reduction of the number of samples and measurements needed to show compliance is desired.

This report evaluates whether the current burden of radionuclide analysis could be reduced during plant operations for LAW vitrification during the River Protection Project mission, in particular, the first 10 years of planned direct feed low-activity waste (DFLAW) treatment.

1.2 Sampling and Feed Qualification

Sampling conditions and design assumptions for the WTP have been described previously [6]. In the sampling protocol, analytical support must be provided at all hours, every day of the year, to meet the WTP production rates for HLW and LAW forms. Currently projected production rates of 6.0 metric tons of glass per day for IHLW and 30 metric tons of glass per day for ILAW is estimated to require ~10,000 samplings per year during routine operations. These sampling estimates will be confirmed during routine operations via further analysis during the waste feed qualification efforts supported by WTP. The work described in this report evaluated analytical requirements for radionuclides for the full Hanford mission as well as the first 10 years of WTP operations, which include DFLAW.

The waste will be removed from the tanks, pretreated to generate LAW feed, and prepared for acceptance into the LAW melter using concentrate receipt vessels. Concentrate receipt vessels are one location where a sample is taken that will be analyzed to determine (a) the amounts of GFCs required and (b) compliance of the expected final product.

After the GFCs are added into the melter feed preparation vessels, another sampling occurs. Once the chemistry is determined through analysis, the LAW feed is released to the melter. A non-routine sampling event may occur upon request to check the acceptability of the final glass product by measuring a piece of glass after pouring.

2.0 Regulations, Requirements, and Contracts

The WTP contract is the governing document through which the U.S. Department of Energy (DOE) Office of River Protection will "manage and oversee the design, construction, and commissioning of the WTP that will treat and immobilize a portion of the waste for ultimate disposal" [2]. Section C of the contract contains the operational specifications that define the requirements that will allow for disposal of the final ILAW product on the Hanford Site.

2.1 Contractual Requirements: WTP Contract

Table S6-2 of the contract (provided in Appendix A of this report) summarizes how various requirements must be satisfied for waste feed qualification and glass product characterization. Regarding chemical and radiochemical composition, the contract requires analysis, demonstration, inspection, and testing. Analysis and demonstration are potentially satisfied using the established process knowledge for certain radionuclide concentrations. Inspection, on the other hand, may require the use of analytical tools and testing, including destructive examination techniques, or measurements, to determine compliance. These terms are further defined in Appendix A of this document. The tank operations contractor will define what these terms mean specifically during operation, as stated in the contract. For the purposes of this document, the contract will be referred to where it specifically defines limits and requirements for radionuclide concentrations, as in specification 2.

Descriptions detailed in the contract include the need for the ILAW product to be a poured glass form enclosed in a sealable, stainless-steel container along with a minimum waste loading based on Na_2O depending on the compositional envelope. Mass for each container is limited to 10,000 kg and the chemical composition of the glass product is required to be documented. According to specification 2.2.2.6.2, "[T]he reported composition shall include elements (excluding oxygen) present in concentrations greater than 0.5 percent by weight and elements and compounds required to meet regulatory and Contract requirements."

Many radionuclides will not exceed the 0.5 wt% amount, and therefore further detail is provided for documentation of the radiological composition in specification 2.2.2.7. This specification points to NUREG/BR-0204 [7] to define what a "significant" concentration is, which in turn uses information from the Code of Federal Regulations (CFR). An exception to this is ^{99}Tc; that is, in specification 2.2.2.7, ^{99}Tc is considered significant if concentrations exceed 0.003 Ci/m^3.

The WTP contract also establishes operating limits in section C.7, facility specification. These values limit certain radionuclides. Subsection C.7.d.iii states that Cs removal via ion exchange resin is established to achieve a ^{137}Cs limit of 0.3 Ci/m^3 in the ILAW product.

Additionally, specification 2.2.2.8 establishes that the radionuclide concentration limits for ^{137}Cs and ^{90}Sr are not to exceed 3 Ci/m^3 and 20 Ci/m^3, respectively. An in-depth discussion of the contractual requirements can be found in the ILAW Product Compliance Plan by Rieck and Nelson [8].

2.1.1 Process Knowledge

Standard 2 (Research, Technology, and Modeling) of the WTP contract discusses the use of material balances and tank assessments. These data can be used in models and to identify characteristics that may limit performance at WTP. The assessment in this work can be used to support the use of the data, which is in the category of information referred to as “process knowledge,” for the determination of limits of operation and treatment rate for the plant. This is impactful because the process knowledge includes tank utilization assessments (TUAs)—a required deliverable under the WTP contract—that document information on various tanks and may provide LAW feed batch estimates. This work used a TUA from 2013 (TUA2013) to understand how the concentrations of radionuclides in various batches compare to the regulatory, reporting, or contractual limits set forth in the contract or other documents referenced therein. Process knowledge would be appropriate for concentrations that are required for reporting only and may be used to understand proximity to contractual or operating limits for WTP.

2.2 Regulatory Requirements: Code of Federal Regulations

The CFR establishes rules and regulations passed down from the U.S. government. 10 CFR 61.55, which was established by the U.S. Nuclear Regulatory Commission (NRC), describes how to classify wastes into the different categories (i.e., Class A, Class B, and Class C), which inevitably impacts the transfer of said waste [7]. This, in turn, impacts what needs to be documented for waste transport and other factors that will affect reporting and waste form compliance. These classes are defined by the values in Table 1 and Table 2. Note that many CFR titles, including 49 and 10 (referenced in this report), are used to govern transportation on public roads. The current plan for disposal does not require that ILAW products be transported to an off-site repository. As this is the case, arguments can be made for removal of associated restrictions that involve transport not relevant to the Hanford Site (i.e., off-site or public roadways) and, as discussed below, removal of regulations that are passed down by bodies that do not govern the Hanford Site (i.e., entities such as NRC that regulate commercial nuclear operations). If transport requirements are removed then the implications of future movement of the ILAW products to an off-site storage would need to be considered.

Table 1. Radionuclide Concentration Levels for Class Designations (source: Table 1 from 10 CFR 61.55)

Radionuclide	Concentration
^{14}C	8 Ci/m^3
^{99}Tc	3 Ci/m^3
^{129}I	0.08 Ci/m^3
Alpha-emitting TRU (with half-life > 5 yrs.)	100 nCi/g
^{241}Pu	3500 nCi/g
^{242}Cm	20,000 nCi/g

Table 2. Radionuclide Concentration Levels for Class Designations (source: Table 2 from 10 CFR 61.55)

Radionuclide	Concentration [Ci/m^3]		
	Col. 1 [Class A]	Col. 2 [Class B]	Col. 3 [Class C]
Total of all nuclides with less than 5-year half-life	700	No limit	No limit
^{3}H	40	No limit	No limit
^{60}Co	700	No limit	No limit
^{63}Ni	3.5	70	700
^{63}Ni in activated metal	35	700	7000
^{90}Sr	0.04	150	7000
^{137}Cs	1	44	4600

Per Table 2, if the concentration of a nuclide listed does not exceed the value in column 1, it is Class A; if it is greater than column 1 but does not exceed column 2, it is Class B. If the concentration exceeds column 2 but is less than column 3, it is Class C. If the concentration is greater than column 3, the material may not be acceptable for disposal in a near-surface facility. If there are mixtures of radionuclides, which is the case for glass waste forms, total concentration is required to be determined by the sum of fractions (SOF) rule. SOF is determined by dividing the concentration of the analyte by the limit as indicated in Table 1 or Table 2 (and the appropriate column) and summing the resulting values. The limits for the radionuclides are determined once the class is established. Once the class is identified, the limits applied to all radionuclides are set by the class designation. Part a.8 of 10 CFR 61.55 also stipulates that the concentrations of radionuclides may be determined by indirect methods, including but not limited to comparing the relative ratios of constituents that are known from process knowledge against one or two measured species.

Specification 2.2.2.8 of the contract requires the contractor to produce an ILAW form with radionuclide concentrations less than Class C limits. Although the NRC does not regulate the WTP or the Hanford Site's Integrated Disposal Facility, the work described in this report does not propose changes to this specification. It is generally not challenging to meet this requirement for pretreated LAW, and the draft DOE order uses similar language [1]. Specification 2 of the WTP contract also references the purpose and use of hazardous materials table of U.S. Department of Transportation (DOT) regulation 49 CFR 172.101 [10]. Appendix B of this report lists the associated reportable quantities for radionuclides of interest. DOT regulations are applicable to open road transportation and not on-site transfers.

2.3 Regulatory Requirements: NUREG/BR-0204

NUREG/BR-0204 is a set of instructions generated by the NRC for completing a manifest after production of low-level radioactive waste, or a waste form [11]. The NRC is a governing body for commercial nuclear facilities, and does not govern the Hanford Site or associated processing. The Hanford Site is governed by DOE, and therefore removal of NUREG/BR-0204 from WTP contractual requirements should be considered. Additionally, if the NRC were the governing body for government sites, which it currently is not, NUREG/BR-0204 would only apply to wastes that are being transported off-site. The current plan is to store the ILAW products on-site at the Integrated Disposal Facility. On-site storage will not result in ILAW products being transported on public roads, and therefore should not fall under the requirements of NUREG/BR-0204.

NUREG/BR-0204 dictates the information that needs to be included when providing documentation on prepared waste forms (e.g., volume, contact radioactivity, chemical description, and other parameters). NUREG/BR-0204 contains the definition of a “significant” radionuclide that is referenced by the WTP contract and provides an impactful bounding condition. NUREG/BR-0204 states that a radionuclide is significant if it is present in concentrations greater than 0.01x the limit as specified in 10 CFR 61.55, or is 0.01x the smallest concentration of the value listed in Table 2 of the same code. As an addition to the restriction described above that references the CFR documentation, NUREG/BR-0204 also requires that radionuclides present in concentrations above 1% of the total activity be reported, even if the concentration limits given above are not exceeded. The limits set forth in NUREG/BR-0204 significantly impact the number of analytes required for reporting. Removing this restriction could reduce the number of required analyses. Further discussion on this topic follows in Section 3.

3.0 Radionuclide Estimates and Measurements

Compiling the information discussed above into a summary of requirements provides an understanding of what is necessary for contractual and regulatory needs, regarding radionuclide analysis for WTP operations during production of ILAW forms. This section discusses the measurement techniques planned for analysis as determined by the data quality objectives as well as calculations completed with TUA2013 values [12]. These calculations were then compared to the requirements enumerated in Section 2 to supply a list of analytes that may be removed as analytes requiring measurement.

3.1 Radionuclide Analyses: Techniques and Issues

Recommendations for analytes to remove from measurement can also be influenced by the method of analysis. For example, if a measurement can be completed on a suite of analytes at minimal extra cost and time, it may be desirable to acquire the data even if it is not expected to cause the final product to be noncompliant.[1] If possible, it is desired to remove challenging-to-measure, or troublesome, components that do not need to be analyzed from the list of required analytes. This is particularly true if they are not expected to impact regulatory compliance or process quality. A list of the troublesome analytes, and why they are difficult or troublesome for the Hanford 222-S Laboratory, is provided below (Table 3).

Table 3. Radionuclide analytes identified as troublesome for the 222-S Laboratory and descriptions of why they cause difficulty in measurement [13].

Radionuclides	Issue/Troublesome Reasons
^{59}Ni, ^{93}Zr, ^{243}Am	222-S Laboratory lacks analysis method
^{137}Cs	Does not meet required detection limit (0.0159 µCi/mL [2])
^{144}Ce, ^{134}Cs, ^{106}Ru, ^{126}Sn, ^{242}Cm	Lack of standards during recent testing[(a)]

(a) It is unclear if the 222-S Laboratory has no standards for these elements, if the standards are not readily available, or if they simply were not used during the testing.

Table 4 provides the methods of analysis used for various radionuclides as described in the Integrated Sampling and Analysis Plan from 2013 [3]. Methods include GEA (gamma energy analysis), ICP-MS (inductively coupled plasma mass spectroscopy), and GPC (gas flow proportional counting).

[1] Although it should be recognized that reporting and quality assurance on opportunistic analytes may sometimes be burdensome.

Table 4. Methods of analysis and acceptance criteria for various radionuclides [3].

		Quality Control Acceptance Criteria	
Constituents	Method	LCS[(a)] % Recovery	Spike % Recovery
^{235}U, ^{238}U, ^{237}Np, ^{232}Th, ^{229}Th	ICP-MS/Alpha counting	80-120%	75-125%
^{232}U, ^{233}U, ^{234}U, ^{236}U, ^{226}Ra	ICP-MS/Alpha counting	N/A	N/A
^{113m}Cd, ^{144}Ce, ^{60}Co, ^{134}Cs, ^{137m}Ba, ^{137}Cs, ^{94}Nb, ^{106}Ru, ^{125}Sb, ^{65}Zn, ^{59}Ni, ^{231}Pa, ^{126}Sn, ^{227}Ac, ^{95}Zr, ^{241}Am	GEA	80-120%	N/A
^{152}Eu, ^{154}Eu, ^{155}Eu	GEA	N/A	N/A
^{129}I	GEA	80-120%	N/A
^{90}Sr, ^{90}Y, ^{63}Ni, ^{93m}Nb, ^{93}Zr	Beta counting (GPC)	80-120%	N/A
^{243}Am, ^{135}Cs, ^{241}Pu, ^{242}Pu, ^{242}Cm, ^{126}Sn, ^{231}Pa	ICP-MS	80-120%	75-125%
^{79}Se, ^{151}Sm, ^{121m}Sn, ^{99}Tc, ^{241}Pu	Liquid scintillation counting	N/A	75-125%
^{238}Pu, ^{242}Pu	Alpha counting	N/A	N/A
^{239}Pu, ^{240}Pu	Alpha counting	80-120%	N/A
^{241}Am, ^{243}Am, ^{243}Cm, ^{244}Cm	Alpha counting	80-120%	N/A

(a) LCS = laboratory control sample: The accuracy of a method is expressed as percent recovery of the control sample. It is a matrix with known concentrations of constituents and is expressed as the amount measured divided by the known concentration multiplied by 100.

3.2 Radionuclide Concentration Calculations

TUA2013 contains a compilation of various batches that are projected wastes to be delivered to LAW treatment facilities [12]. The batch estimates are based on the known compositions of the tanks, process knowledge of how the tank chemistries change over time, and any measurements that were previously completed. The waste feed compositions represent a scenario of no oxidative or caustic leaching[1] after treatment for cesium removal, and the estimates contain 746 unique batches for the full mission.

Appendix C of this document provides the results of the analyses for significant analytes in each of the batches for the full Hanford mission as well as for DFLAW, which is defined as the first 10 years of plant operations (the first 386 batches). These waste estimates were used to calculate anticipated levels of radionuclides in potential glass compositions at 26 wt% Na_2O (soda) waste loading in all glasses. The Na_2O concentrations in each of the waste feed batches were normalized to 26 wt%, which in turn provided an overall waste loading level for mass of waste per mass of glass, in kilograms. Note that the calculations completed in this document assume 100% retention of the radionuclides in the final waste form. It is known that volatiles are lost to the off-gas during melting but effective use of recycle will bring them back to feed concentrations for most elements (excluding species such as H, Hg, C, and N) [14].

After determining the waste loading, based on the normalized soda loading of 26 wt%, and using it to establish the amount of each radionuclide expected in a glass composition, the mass of radionuclides per mass of glass was then converted to either curies of radionuclide per mass of glass or curies of radionuclide per volume of glass, depending on the units of the limits in the

[1] No leaching case was selected to best represent the DFLAW phase of operations.

tables discussed above. The conversion of mass of radionuclides to curies of radionuclides per mass of glass was done with the specific activities and glass density discussed by Kim and Vienna [14]. Conversion of the values from mass of glass to volume of glass was done with a representative, average value for density of LAW glass (2.65 g/cm^3 [14]). The converted values, whose final units were determined according to the regulations set forth for comparison, were then compared to the various limits for reporting or documentation as described below.

3.3 Radionuclide Estimate Results

Specification 2.2.2.7 of the WTP contract describes requirements for documentation of radiological composition for the waste forms [2]. Specification 2.2.2.7 uses NUREG/BR-0204 [11] and 49 CFR 172.101 [10] to define what are “significant” radionuclides and should, in turn, be reported. As mentioned in Section 2.1.1 of this document, process knowledge could be employed to reduce measurements for analyses that are for reporting. Defensible values are required for radionuclide reporting, and inventory or assessment data may be used to fulfill that requirement.

3.3.1 Application of NUREG/BR-0204 and WTP Contract Limits

The estimates of radionuclide concentrations were determined from TUA2013 for 386 batches (DFLAW) and 746 batches (full Hanford mission) [12]. The focus will be on DFLAW processing. Table 5 shows the radionuclides that were calculated to be significant according to NUREG/BR-0204 alone as well as NUREG/BR-0204 with the restrictions listed in the WTP contract for ^{90}Sr, ^{99}Tc, and ^{137}Cs. It should be noted that ^{90}Sr, ^{99}Tc, and ^{137}Cs need to be measured regardless of what is determined via waste feed estimates. Appendix C of this document lists all of the analytes of interest as well as the number of batches for which they were determined to be significant for DFLAW as well as the full mission.

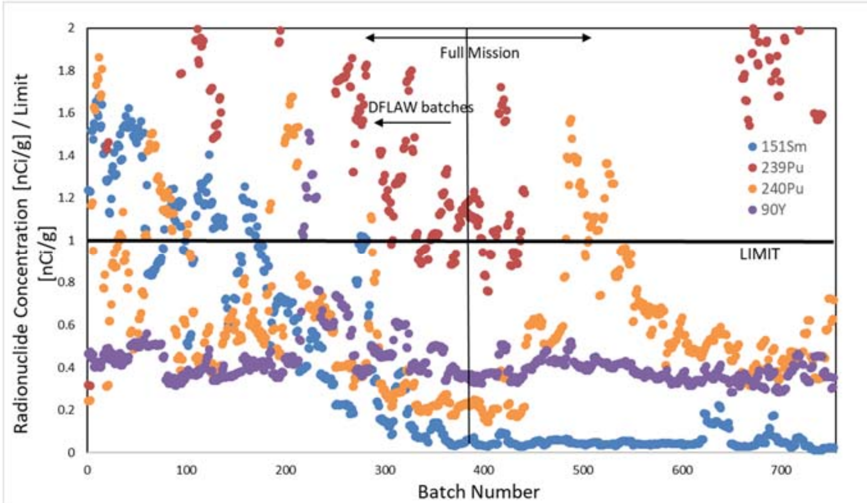
The values for DFLAW were divided by the total number of batches to provide the percentages shown below (Table 5). If a radionuclide isn’t listed, then it was found to not be significant for any of the 386 batches. Note that the contributions of significant batches mainly occur in the first 10 years of operations (i.e., DFLAW); therefore, the full Hanford mission has similar values for significant batches, with the only exception being when the analyte concentration relative to total activity is determined. This results in the recommendations that are discussed in Section 4 of this document being applicable to both the full mission and DFLAW.

Table 5. List of analytes determined as significant for batch estimates during DFLAW processing according to NUREG/BR-0204 and the WTP contract in conjunction with NUREG/BR-0204, and the percentage of batches where they were found to be significant as calculated in this work.

	Percentages of Batches with Significant Amounts of Analyte for DFLAW		
Analyte	NUREG/BR-0204	NUREG/BR-0204 (Total Activity)	WTP and NUREG/BR-0204
^{137}Cs	100%	0%	100%
^{151}Sm	33%	100%	100%
^{239}Pu	94%	-	94%
^{240}Pu	18%	-	18%
^{241}Am	99%	1%	99%
^{63}Ni	100%	49%	100%
^{90}Sr	100%	100%	100%
^{90}Y	4%	100%	4%
^{99}Tc	100%	100%	100%

Of the 44 analytes reported in the TUA2013 estimates, only 9 were found to be greater than the concentration specified in the requirements for > 1% of the total number of batches with the limits applied based on the WTP contract as well as NUREG/BR-0204. The TRU isotopes were individually compared to the limit established in Table 1 of 100 nCi/g.

To understand how close to the limit each of the radionuclide concentrations were for each batch, the amount calculated from the TUA2013 values was divided by the NUREG/BR-0204 limit, or specified concentration, and plotted against batch number. The radionuclides from Table 5 are shown below (Figure 1) except for ^{90}Sr, which significantly exceeded its documented concentration requirement in all batches for the full mission.



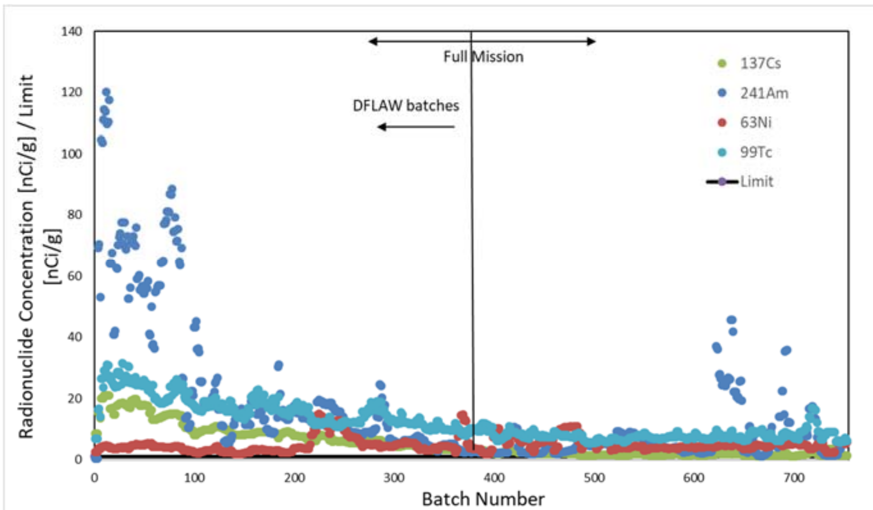


Figure 1. Radionuclide concentration fraction, relative to its respective concentration for reporting as noted in NUREG/BR-0204, versus batch number. The first 386 batches are representative of DFLAW. (Some values for ^{239}Pu are in excess of 2 and are not shown).

^{90}Y was typically around 50% of the limit, except for certain batches during the first 10 years. ^{151}Sm and ^{240}Pu had many batches that exceeded the limit during the first 10 years, and ^{240}Pu exceeded the limit for some batches during the rest of the mission. If concentrations and their proximity to the limit are used for determining whether an analyte should be measured, a safety factor, or buffer for uncertainty, should be employed. For example, it's unlikely that radionuclides that are less than 20% of the limit need to be measured. The other radionuclides represented in the TUA2013 batch estimates are shown in the plots below (Figure 2).

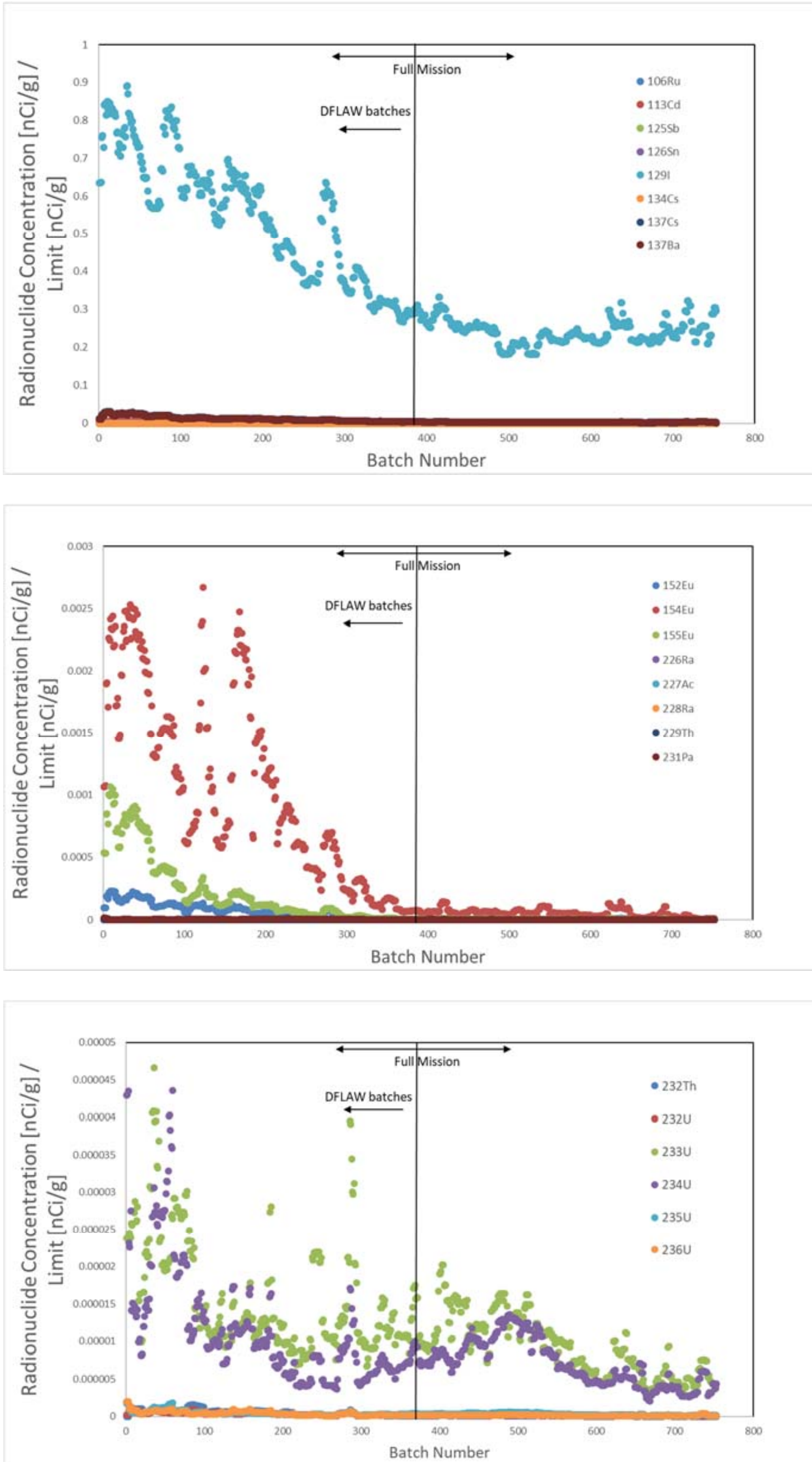


Figure 2. Plots of all radionuclides that are not included in Figure 1 and their relative amounts to the respective NUREG/BR-0204 limits versus batch number.

Only ^{129}I exceed greater than 1% of the concentration for reporting as specified in NUREG/BR-0204; all other radionuclides were well below, as seen in Figure 2a, b, and c.

Note that while 3H and 14C were included in the batch feed estimates, they are not represented in the calculations as they are not retained in the ILAW waste form. The addition of WTP contract requirements to the NUREG/BR-0204 limit only impacts the ^{90}Sr value, if it assumed that the WTP contract supersedes other referenced documents. The limit for ^{90}Sr in the WTP contract is 20 Ci/m^3 [2]. If the NUREG/BR-0204 limit was applied instead, the minimum for ^{90}Sr would be 7.03 Ci/m^3 (0.26 MBq/cm^3) [7]. This change resulted in a decrease in the percentage of batches failing to stay below the ^{90}Sr limit from 25% to only 2%. For the purposes of this document, radionuclides that exceed their respective limits in a percentage of batches greater than 1% will not be recommended for removal from required measurements. This 1% value is suggested as a conservative approach for eliminating batches. If it is determined that the threshold should be higher, more analytes may be suggested for removal.

3.3.2 Application of 49 CFR 172.101 and NUREG/BR-0204 Limits

The WTP contract refers to 49 CFR 172.101 to establish significant analytes [3]. This code contains a purpose of use and hazardous materials table that lists minimum values for significance of various radionuclides. The results of how many batches contained significant amounts of any given radionuclide when compared to 49 CFR 172.101 are given in Table 6 of this document. Additionally, as the WTP contract refers to NUREG/BR-0204 and 49 CFR 172.101, Table 6 also provides the number of batches that contain significant amounts of the radionuclide with both limits applied.

Table 6. List of analytes, and the percentages of batches, that are significant during DFLAW as determined by 49 CFR 172.101 as well as 49 CFR 172.101 coupled with NUREG/BR-0204.

	Percentages of Batches with Significant Amounts of Analyte	
Analyte	49 CFR 172.101	49 CFR 172.101 and NUREG/BR-0204
^{113}Cd	99%	99%
^{126}Sn	57%	57%
^{129}I	100%	100%
^{137}Cs	99%	99%
^{151}Sm	100%	100%
^{227}Ac	74%	74%
^{231}Pa	4%	4%
^{232}Th	12%	12%
^{237}Np	97%	97%
^{238}Pu	98%	98%
^{239}Pu	100%	100%
^{240}Pu	100%	100%
^{241}Am	100%	100%
^{241}Pu	50%	50%
^{243}Am	18%	18%
^{244}Cm	75%	75%
^{63}Ni	2%	2%
^{90}Sr	100%	100%
^{90}Y	100%	100%
^{93}Zr	91%	91%
^{99}Tc	99%	100%

Of the 21 analytes determined to be significant in at least 1% of the batches when considering 49 CFR 172.101, only 2 were significant in less than 5% of the batches (^{231}Pa = 4% and ^{63}Ni = 2%). A conservative cutoff point of 1% significant batches is used to make recommendations in this report; however, if that percentage were increased to 5%, ^{231}Pa and ^{63}Ni would be good candidates for elimination from measurement. The combination of 49 CFR 172.101 with NUREG/BR-0204 appears to only impact ^{99}Tc, as evidenced by the increase in percentage of significant batches from 99% to 100% (Table 6). Note that for the full Hanford mission, ^{63}Ni is only significant in 1% of the estimated batches (Appendix C).

The concentrations for each analyte were determined from the TUA2013 values and then divided by the value of significance as stated in 49 CFR 172.101. That maximum ratio for analytes where the value is less than 1.0 for most of the batches in the first ten years is shown below (Figure 3).

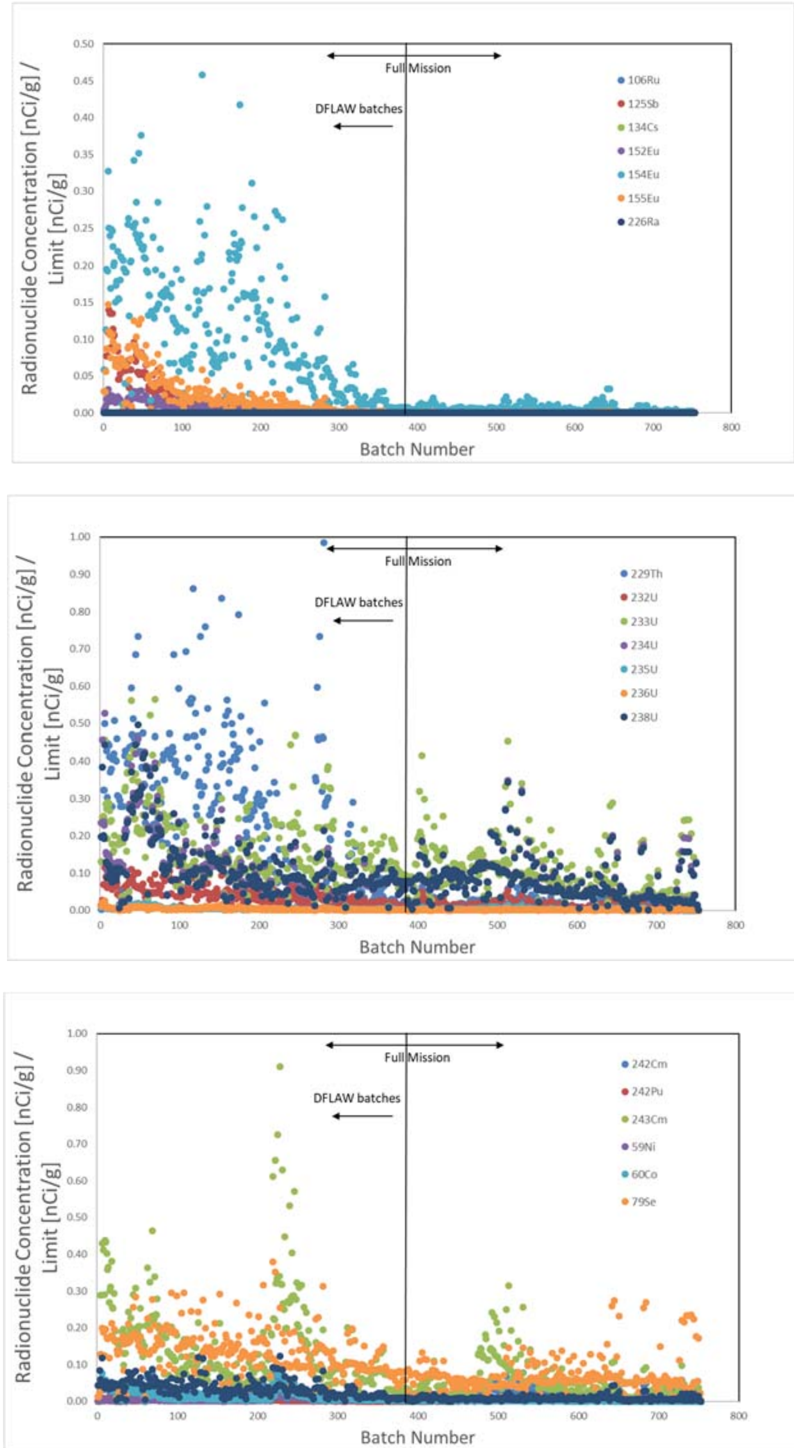


Figure 3: Plots of the concentration of radionuclide isotope concentration normalized to their respective reporting value as defined in 49 CFR 172.101 versus batch number. The radionuclides shown have a maximum ratio less than one.

Out of the 20 isotopes plotted above in Figure 3, six have ratios that exceed 0.2 of the reporting values documented in 49 CFR 172.101: ^{106}Ru, ^{229}Th, $^{233/234/238}$U, ^{234}Cm, and ^{79}Se. Out of those six, only four have batches that are in excess of 0.5 and those events primarily occur during DFLAW operations (^{229}Th , $^{233/234}$U, and ^{243}Cm).

4.0 Recommendations

Generally, it is recommended that process knowledge be used for radionuclide concentrations that are required for reporting. If necessary, measurements for reporting can be determined based on how close the concentrations are to the specified limit. As shown Figure 2, if projected estimates are below a certain safety factor, previous data could be used for reported values.

Based on the calculations and requirements discussed above, this section describes how the elimination of specific requirements can enable a reduction in required measurements. The values discussed above are based on projected batch estimates for DFLAW operations, but it was found that the significant contributions of analyte concentrations are similar for the full Hanford mission as well. This is because most of the high concentrations of radionuclides occur during the first 10 years of the mission.

The following analytes were not found to be significant for any of the regulations or requirements described in the previous sections, based on the TUA2013 values for no oxidative or caustic leaching estimates with a forced Na_2O of 26 wt%. Note that 26 wt% is likely larger than the waste loadings that will be achieved, particularly during the first 10 years of operation. As this is the case, the calculations above and the recommendations below may be considered conservative, and, if conservatism were removed, the number of instances with significant levels of analytes might be lower due to lower concentrations in the batch estimates.

Table 7. Analytes determined to not be significant in a percentage of DFLAW batches equal to or less than 1% for requirements for the specified document.

Limiting Document	Troublesome Analytes [13]	TRU Analytes	Other Analytes
All Documents (never significant)	^{106}Ru, ^{134}Cs, ^{242}Cm, ^{59}Ni	^{242}Cm, ^{242}Pu, ^{243}Cm	^{125}Sb, ^{152}Eu, ^{154}Eu, ^{155}Eu, ^{226}Ra, ^{228}Ra, ^{229}Th, ^{232}U, ^{233}U, ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{60}Co, ^{79}Se, ^{93}Nb
Significant for 49 CFR 172.101 only	^{93}Zr, ^{126}Sn, ^{243}Am	^{238}Pu, ^{237}Np, ^{244}Cm, ^{243}Am	^{137}Ba, ^{129}I, ^{137}Cs, ^{113}Cd, ^{227}Ac
Significant for NUREG/BR 0204 and 49 CFR 172.101 only	-	-	^{241}Pu, ^{232}Th, ^{231}Pa, ^{137}Cs, ^{63}Ni

The analytes listed in Table 7 were shown to be below the limits of "significance" when compared to the indicated documentation. The "All Documents" row indicates analytes that will be insignificant based on calculations completed with TUA2013 batch estimates in all cases [12]. The list of radionuclides likely not requiring measurement without removal of any regulations or requirements includes the following troublesome analytes: ^{106}Ru, ^{134}Cs, ^{242}Cm, and ^{59}Ni. Analytes for which less than 1% of batches had significant concentrations are shown above (Table 7), and the corresponding regulation or contract is indicated as well.

If 49 CFR 172.101 were removed from the WTP contract, measurement of the analytes given in the top two rows of Table 7 would likely be unnecessary. This would result in removal of the following troublesome analytes from analysis, in addition to the list in the previous paragraph: ^{93}Zr, ^{126}Sn, and ^{243}Am. If NUREG/BR-0204 requirements were removed as well, none of the analytes listed in Table 7 would require measurement.

5.0 Summary

The WTP contract and NUREG/BR-0204 dictate the limits of radionuclides for operating and reporting compliance for processing of low-activity waste. This, in turn, drives the determination of what radionuclides are required to be reported for either compliance documents or regulatory requirements. A total of 22 of the 44 analytes were found to not be significant based on the calculations determined from the batch estimates. Those 22 analytes were as follows: ^{106}Ru, ^{125}Sb, ^{134}Cs, ^{137m}Ba, $^{152/154/155}$Eu, $^{226/228}$Ra, ^{229}Th, $^{232/234/235/236/238}$U, $^{242/243}$Cm, ^{242}Pu, ^{59}Ni, ^{60}Co, ^{79}Se, and ^{93}Nb. Many troublesome analytes (i.e., ^{106}Ru, ^{134}Cs, ^{242}Cm, and ^{59}Ni; [13]) were shown to not be significant in a large portion of batch estimates analyzed based on TUA2013 values compared to the regulations set forth in specification 2 of the WTP contract [12]. As the analytes listed above are shown to not be significant, it may be prudent to determine their concentrations based on process knowledge or databases such as the best basis inventory without requiring measurement during WTP operations.

Figures were presented which showed how certain batches performed with their isotope concentrations relative to the respective significance value for NUREG-BR/0204 and 49 CFR 172.101. Those values would need a defined safety factor to account for uncertainty and could then be used to define which isotopes should be measured for reporting. For example, as mentioned above, values of 0.2 or less could be reported based on process knowledge and greater ratios values than that may require measurement, especially if more than 0.8.

NUREG/BR-0204 and 49 CFR 172.101 were generated by a governing body regulating commercial facilities and are mainly used to regulate the transport of hazardous materials. As the Hanford Site is a government entity (governed by the DOE) and low-activity waste disposal will occur on-site, (i.e., no need for transport on public infrastructure), there is little reason for these regulations to dictate disposal of Hanford low-activity waste forms. Removal of NUREG/BR-0204 and 49 CFR 172.101 regulatory limits would result in the following analytes not being significant according to failed batch analysis: ^{93}Zr, ^{126}Sn, and ^{243}Am in addition to the others mentioned above.

The suggestions provided in this document are for low-activity waste processing operations and are based on the estimated number of batches where analytes are projected to be significant or exceed their limit. This information does not account for which analytes will be measured by a particular method and how that impacts which analytes should be measured. Additionally, certain analytes, such as ^{99}Tc and ^{137}Cs, are required to be measured regardless of their relative amounts compared to their established limits.

6.0 References

[1] Nguyen DM (2018). *Integrated DFLAW Feed Qualification Data Quality Objectives*. Washington River Protection Solutions, LLC, U.S. Department of Energy, Richland, WA, RPP-RPT-59494.

[2] WTP Contract No. DE-AC27-01RV14136 (2000). U.S. Department of Energy, Richland, WA.

[3] Arakali A and J Johnston (2013). *Integrated Sampling and Analysis Plan (ISAP)*. Bechtel National, Inc., Richland, WA, 24590-LAB-PL-OP-12-0001, Rev. 0.

[4] Nelson J, DS Kim, L Petkus, and JD Vienna (2011). *ILAW Product Compliance Plan*. Bechtel National, Inc., Richland, WA, 24590-WTP-PL-RT-03-001, Rev. 5.

[5] Poirier MR, AM Howe, FR Miera, M Stone, and CC DiPrete (2018). *WTP Real-Time In-Line Monitoring Program Task 1: LAW and EMF Analytes and Properties – Functional Requirements*. Savannah River National Laboratory, Aiken, SC, SRNL-RP-2017-00239, Rev. 0.

[6] Bechtel National, Inc. *Analytical Laboratory Design Requirements: WTP Sampling and Analysis Plan (S&AP)*. Richland, WA, 24590-WTP-PL-PR-01-004.

[7] 10 CFR 61.55, *Waste Classification* (2017). U.S. Nuclear Regulatory Commission, Washington, D.C.

[8] Rieck BT and JL Nelson (2017). *ILAW Product Compliance Plan*. Bechtel National, Inc., Richland, WA, 24590-LAW-PL-PENG-17-0001, Rev 0.

[9] DOE Order 435.1 (1999). *Radioactive Waste Management*. U.S. Department of Energy, Richland, WA.

[10] 49 CFR 172.101 (2017). Purpose and use of hazardous materials table. U.S. Department of Transportation, Washington, D.C.

[11] DOT (1998). *Instructions for Completing NRC's Uniform Low-Level Radioactive Waste Manifest*. U.S. Department of Transportation, Washington, D.C., NUREG/BR-0204, Rev. 2.

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[13] Sasaki LM (2018). *Evaluation of Tank 241-AP-107 Direct Feed Low-Activity Waste Pre-Qualification Sampling and Analysis*. Washington River Protection Solutions, LLC, Richland, WA, RPP-RPT-60946, Rev. 00.

[14] Kim DS, JD Vienna, and AA Kruger (2012). *Preliminary ILAW Formulation Algorithm Description, 24590 LAW RPT-RT-04-0003, Rev. 1*. U.S. Department of Energy, Office of River Protection, Richland, WA, ORP-56321.

Appendix A – Definition of Terms from the WTP Contract

The table and text below define how the contractor shall characterize and qualify the final waste products and generated secondary waste using analysis (A), testing (T), demonstration (D), and inspection (I).

Table S6-2. Qualification and Characterization.

Requirement	Qualification	Product Characterization
Chemical and Radiochemical Composition	A, D, I, T	A, D, I, T
Dangerous and Hazardous Wastes	A, D, I, T	A, D, I, T
Waste Loading	A, D, T	A, D, T
Waste Form Leaching/Durability	A, T	A, T
Waste Form Stability	A, D, T	D
Free Liquids, Explosivity, Pyrophoricity, Organic Materials, and Gases	A, D, I	A, D, I
Heat Generation and Surface Temperature	A	A
Dose Rate and Criticality	A	A, I
Package and Canister Dimensions	D, I	D, I
Weight and Mass	A, D, I	D, I
Void Space and Fill Height	D	D, I
Package and Canister Materials	D, I	D, I
Package and Canister Mechanical Strength	A, D, T	D
Labeling	D, I	I
Package and Canister Handling Features	D, I	D, I
Package and Canister Closure and Sealing	D, I	D, I
Surface Contamination	D	D, I

Legend:
A = Analysis
D = Demonstration
I = Inspection
T = Testing

Definitions taken from WTP Contract Section C; Contract No. DE-AC27-01RV14136 Modification No. 390

1. Analysis (A)—As used in the specifications, an analysis is a set of engineering or scientific calculations that demonstrate that a product meets or exceeds a specification requirement. These calculations are typically based upon available data and assumptions regarding process operating conditions or materials. Analysis is required to identify conditions or assumptions, which might limit validity, and to identify specific documentation or measurements made during production to ensure validity (e.g., waste loading, container material, process additives, process measurements, etc.). Analyses shall be conducted and documented in enough detail in such a way that a knowledgeable technical person can review and concur in their accuracy and validity. Evidence of peer review for accuracy for each analysis shall be provided. An analysis will be considered to demonstrate compliance with specification requirements when (1) approved by DOE; and (2) when the conditions for validity or assumptions are verified by independent means (e.g., process control records, raw material certifications).

2. Demonstration (D)—A demonstration is the proof-of-principle of a specimen, article, or process test used to verify conformance to the conditions of an analysis or product specification. Demonstrations are conducted where analysis is insufficient to provide proof-of-product acceptability or where analysis indicates the need for verification of assumptions (e.g., waste loading, explosivity, scale-up, process control). Demonstration reports shall identify (1) the demonstration being conducted; (2) the limits of the demonstration's validity; and (3) those inspections or tests that will be conducted during operations to confirm that the demonstration results are still applicable to the product being produced. Proposed demonstrations will be submitted as part of the compliance plans. A demonstration will constitute verification of compliance with a specification requirement when (1) it has been approved by DOE; and (2) when the conditions for validity or assumptions have been verified by independent means (e.g., process control records, raw material certifications) during operation.
3. Inspection (I)—Inspection is a nondestructive examination or measurement of a product characteristic that confirms compliance with product specifications. Inspections are conducted when product characteristics can be easily determined by direct measurement (e.g., weight, dimensions, labeling, external temperature, etc.) or where the results of the calculations leave some doubt as to satisfaction of the product requirements.
4. Test (T)—A test is the evaluation of a product characteristic in which representative samples are destructively examined or measured to confirm compliance with product specifications. Tests are typically conducted where product characteristics cannot be readily determined by inspections, or where an inspection by itself, does not provide adequate confirmation of compliance (e.g., chemical composition, radionuclide release rate). Upon request by DOE, the Contractor shall split and provide DOE samples obtained from or representative of the delivered products. The Contractor is responsible for defining what constitutes a statistically representative sample (e.g., based on the extent of process control achieved for that product).
5. Qualification—Qualification is composed of activities conducted by the Contractor to provide confidence, prior to full-scale production operations, that the planned immobilized waste products and secondary wastes will conform to the specifications in the Contract.
6. Characterization—Characterization is composed of activities conducted by the Contractor to provide confidence that the actual immobilized waste products and secondary wastes produced during production operations conform to the specifications and requirements in the Contract.
7. Certification—Certification is the endorsement or guarantee by the Contractor that an immobilized waste product or secondary waste conforms to the Contract requirements and specifications.
8. Validation—Validation is composed of activities conducted by the Contractor with actual wastes or with full-scale process equipment to confirm that the results of the analyses, demonstrations, inspections, and test(s) conducted by the Contractor to qualify a product or process are representative of the product and process characteristics.
9. Verification—Verification is composed of activities conducted by DOE to confirm that each immobilized waste product or secondary waste conforms to the Contract requirements and specifications.

Appendix B – Limits Established in 49 CFR 172.101

This table provides the reportable quantity limits for radionuclides discussed in this document. The limits shown below are in curies and provided from 49 CFR 172.101, the Purpose and use of hazardous materials table [10].

Radionuclide	Limit [Ci]		Radionuclide	Limit [Ci]
^{106}Ru	1		^{236}U	0.1
^{113}Cd	0.1		^{237}Np	0.01
^{125}Sb	10		^{238}Pu	0.01
^{126}Sn	1		^{238}U	0.1
^{129}I	0.001		^{239}Pu	0.01
^{134}Cs	1		^{240}Pu	0.01
^{137}Cs	1		^{241}Am	0.01
^{137m}Ba	NL		^{241}Pu	1
^{151}Sm	10		^{242}Cm	1
^{152}Eu	10		^{242}Pu	0.01
^{154}Eu	10		^{243}Am	0.01
^{155}Eu	10		^{243}Cm	0.01
^{226}Ra	0.1		^{244}Cm	0.01
^{227}Ac	0.001		^{59}Ni	100
^{228}Ra	0.1		^{60}Co	10
^{229}Th	0.001		^{63}Ni	100
^{231}Pa	0.01		^{79}Se	10
^{232}Th	0.001		^{90}Sr	0.1
^{232}U	0.01		^{90}Y	10
^{233}U	0.1		^{93}Zr	1
^{234}U	0.1		^{93m}Nb	100
^{235}U	0.1		^{99}Tc	10

Appendix C – Significant Batches Results Using TUA2013 Waste Feed Batch Estimates

Below is the full list of analytes and the number of projected no leach TUA2013 monthly totalizer batches where the analytes were found to be significant. The combination of 49 CFR 172.101 and NUREG/BR-0204 may result in a number greater than the total batches due to the individual contribution of each limit to significant analyte levels in each batch

Table C.1. Analytes and their projected number of batches were the analytes were found to be significant. Cell highlight refers to troublesome components according to Hanford 222-S Laboratory [11]; red text refers to TRU analytes.

	FULL MISSION: # of batches with significant levels of each analyte [746 total batches]					DFLAW (first 10 years) # of batches with significant levels of the analytes [386 total batches]				
Analyte	NUREG/ BR-0204	NUREG/ BR-0204 [Total Activity]	WTP + NUREG/ BR-0204	49 CFR 172.101	49 CFR 172.101 + NUREG/ BR-0204	NUREG/ BR-0204	NUREG/ BR-0204 [Total Activity]	WTP + NUREG/ BR-0204	49 CFR 172.101	49 CFR 172.101 + NUREG/ BR-0204
^{106}Ru	0	0	0	0	0	0	0	0	0	0
^{113}Cd	0	0	0	712	712	0	0	0	384	384
^{125}Sb	0	0	0	0	0	0	0	0	0	0
^{126}Sn	0	0	0	223	223	0	0	0	221	221
^{129}I	0	0	0	746	746	0	0	0	386	386
^{134}Cs	0	0	0	0	0	0	0	0	0	0
^{137}Ba*	0	0	0	-	-	0	0	0	-	-
^{137}Cs	386	0	386	717	717	746	0	746	384	384
^{151}Sm	127	746	127	726	853	127	386	127	385	512
^{152}Eu	0	0	0	0	0	0	0	0	0	0
^{154}Eu	0	0	0	0	0	0	0	0	0	0
^{155}Eu	0	0	0	0	0	0	0	0	0	0
^{226}Ra	0	0	0	0	0	0	0	0	0	0
^{227}Ac	0	0	0	364	364	0	0	0	285	285
^{228}Ra	0	0	0	0	0	0	0	0	0	0
^{229}Th	0	0	0	0	0	0	0	0	0	0
^{231}Pa	0	0	0	16	16	0	0	0	16	16
^{232}Th	0	0	0	45	45	0	0	0	45	45
^{232}U	0	0	0	0	0	0	0	0	0	0
^{233}U	0	0	0	0	0	0	0	0	0	0
^{234}U	0	0	0	0	0	0	0	0	0	0

Analyte	FULL MISSION: # of batches with significant levels of each analyte [746 total batches]					DFLAW (first 10 years) # of batches with significant levels of the analytes [386 total batches]				
	NUREG/ BR-0204	NUREG/ BR-0204 [Total Activity]	WTP + NUREG/ BR-0204	49 CFR 172.101	49 CFR 172.101 + NUREG/ BR-0204	NUREG/ BR-0204	NUREG/ BR-0204 [Total Activity]	WTP + NUREG/ BR-0204	49 CFR 172.101	49 CFR 172.101 + NUREG/ BR-0204
^{235}U	0	0	0	0	0	0	0	0	0	0
^{236}U	0	0	0	0	0	0	0	0	0	0
^{237}Np	0	0	0	681	681	0	0	0	374	374
^{238}Pu	0	0	0	703	703	0	0	0	379	379
^{238}U	0	0	0	0	0	0	0	0	0	0
^{239}Pu	704	0	704	746	1450	364	0	364	386	750
^{240}Pu	111	0	111	742	853	68	0	68	386	454
^{241}Am	743	14	743	746	1489	383	5	383	386	769
^{241}Pu	0	0	0	206	206	0	0	0	193	193
^{242}Cm	0	0	0	0	0	0	0	0	0	0
^{242}Pu	0	0	0	0	0	0	0	0	0	0
^{243}Am	0	0	0	83	83	0	0	0	70	70
^{243}Cm	0	0	0	0	0	0	0	0	0	0
^{244}Cm	0	0	0	362	362	0	0	0	289	289
^{59}Ni	0	0	0	0	0	0	0	0	0	0
^{60}Co	0	0	0	0	0	0	0	0	0	0
^{63}Ni	746	541	0	11	11	386	188	0	7	7
^{79}Se	0	0	0	0	0	0	0	0	0	0
^{90}Sr	746	746	9	746	755	386	386	9	386	395
^{90}Y	15	746	15	746	761	15	386	15	386	401
^{93}Nb	0	0	0	0	0	0	0	0	0	0
^{93}Zr	0	0	0	439	439	0	0	0	353	353
^{99}Tc	746	746	746	723	1469	386	386	386	382	768

Analyte cell highlight = troublesome components according to Hanford 222-S Laboratory [13]; red text = TRU analytes; orange highlight for batches = no significant batches for any documentation for a given analyte.
*^{137m}Ba did not have a limit in the materials table, 49 CFR 172.101.

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