PNNL-38102, Rev. 0
DFTP-RPT-046, Rev. 0

Ion Exchange Processing of AW-105 Hanford Tank Waste through Crystalline Silicotitanate in a Staged 2- then 3-Column System

September 2025

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Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Pacific Northwest National Laboratory
Richland, Washington 99354

Summary

The Hanford Site stores an estimated 56 million gallons of mixed radioactive and chemically hazardous waste in large underground tanks. In support of the Direct Feed Low-Activity Waste (DFLAW) program for expediting Hanford tank waste supernate treatment, laboratory-scale ion exchange processing using prototypic unit operations was conducted on AW-105 tank waste at the Pacific Northwest National Laboratory Radiochemical Processing Laboratory.

This report describes the small-scale ion exchange testing with 9.2 L of diluted and filtered supernate from tank 241-AW-105 (hereafter referred to as AW-105) at 16 °C (61 °F). One of the waste acceptance criteria (WAC) for the Hanford Waste Treatment and Immobilization Plant (WTP) Low-Activity Waste Facility is that the waste must contain less than 3.18×10^{-5} Ci ^{137}Cs per mole of Na.[1] For the AW-105 tank waste to meet this criterion, only 0.225% of the influent ^{137}Cs concentration may be delivered to the WTP; this requires a Cs decontamination factor of 445. Testing with AW-105 matched current Tank Side Cesium Removal (TSCR) facility prototypic operations, where a lead-lag configuration was used until the lag column reached the WAC limit, then a polish column was brought online for continued processing in a lead-lag-polish column configuration. Feed was processed at 1.9 bed volumes (BVs) per hour; the flowrate, in terms of contact time with the crystalline silicotitanate (CST) bed, matched the expected flowrate at TSCR. The Cs-decontaminated product was retained for vitrification testing (to be reported separately).

The lead column reached 83% Cs breakthrough after processing ~1500 BVs of feed; the 50% Cs breakthrough was interpolated from the breakthrough data and occurred at 1041 BVs. Despite the AW-105 supernate having a significantly higher K concentration (0.58 M compared to 0.10 M), testing compared to previous AP-107 ion exchange column testing at 16 °C showed no significant difference in BVs processed to reach the WAC on the lead column and lag columns (only an ~20 BV decrease in volume processed). The negligible differences in capacity despite the 5x concentration differences in K were determined to be due to the significantly lower NO_3 concentration in the AW-105 supernate compared to the AP-107 tank waste matrix. A comparison in breakthrough curves for the two tests also indicated slightly faster kinetic behavior in the AW-105 supernate, with the variations in feed matrices (lower NO_3 concentration) likely responsible for the deviation. The Cs effluent from the lag column reached the WAC limit after processing 772 BVs. Anticipating this breakthrough point, the polish column was preemptively installed around 675 BVs. Cs breakthrough from the lag column began at 300 BVs, reaching 1.10×10^{1} µCi/mL, or 14.13 % Cs breakthrough, after processing all 1500 BVs of feed. The polish column processed nominally 830 BVs and reached 2.10×10^{-1} µCi/mL, or 0.27 % Cs breakthrough, at the conclusion of the test. Table S.1 and Figure S.1 summarize the observed column performance and relevant Cs loading characteristics.

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[1] 24590-WTP-ICD-MG-01-030, Rev. 1. 2021. *ICD 30 – Interface Control Document for DFLAW Feed*. Bechtel National, Inc. (River Protection Project Waste Treatment Plant), Richland, Washington.

Table S.1. AW-105 Column Performance Summary with CST at 16 °C

Column	WAC Limit Breakthrough (BVs)	50% Cs Breakthrough (BVs)	^{137}Cs Loaded (µCi)	Cs Loaded (mmoles Cs/g CST)
Lead	230	1041[(a)]	5.02E+05	0.0424
Lag	772	2089[(a)]	2.02E+05	0.0176
Polish	1426	NA	1.07E+04	0.0009

(a) Extrapolated value
BV = bed volume, 6.0 mL
The time-weighted average flowrate was 1.95 BV/h.

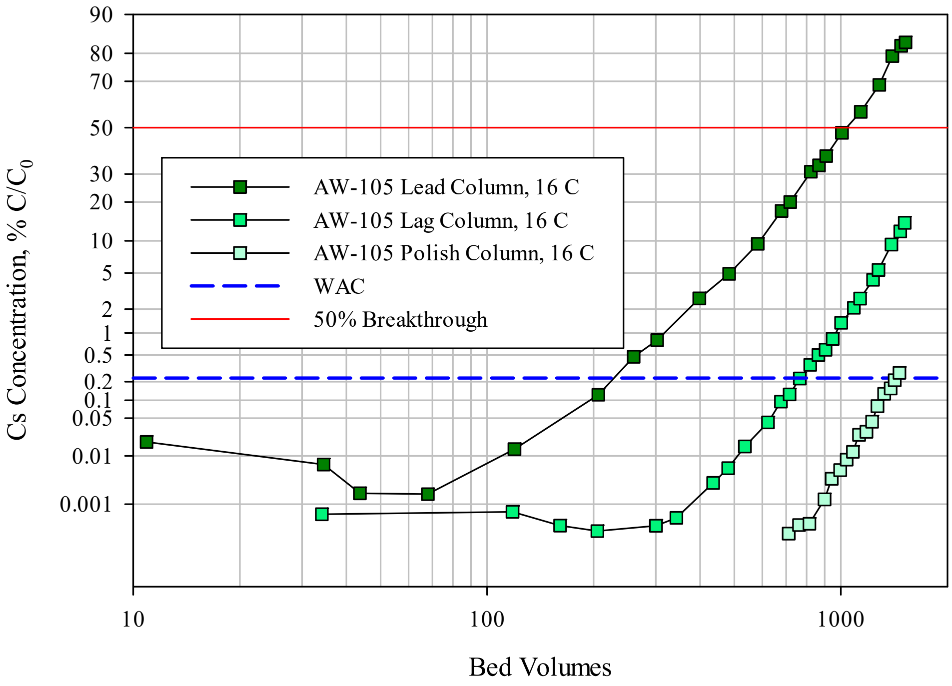

Figure S.1. Lead, Lag, and Polish Column Cs Load Profiles for AW-105 at 16 °C

The AW-105 composite feed and composite effluent were characterized to understand the fractionation of selected analytes and radionuclides. Table S2 summarizes the concentrations and recoveries of the selected analytes.

Table S.2. Recoveries of Analytes of Interest in the AW-105 Effluent

	Analyte	Feed Concentration (M)	Effluent Concentration (M)	Fraction in Effluent
Metals / Non-metals	Al	3.17E-01	3.22E-01	99%
	Cr	6.22E-03	6.17E-03	97%
	Fe	[6.3E-05]	[7.4E-05]	115%
	K	5.81E-01	5.69E-01	96%
	Na	5.63E+00	5.56E+00	97%
	Ni	[9.5E-05]	[1.4E-04]	149%
	P	[1.3E-02]	[1.3E-02]	97%
	S	[4.2E-02]	[4.4E-02]	104%
	Ti	9.09E-06	[1.5E-05]	160%
	Zn	5.09E-04	[4.9E-04]	95%
Hot persulfate oxidation	Total organic C	1.01E-01	1.03E-01	103%
	Total inorganic C	6.19E-01	6.10E-01	98%
Radioisotopes		µCi/mL	µCi/mL	
	^{137}Cs	7.60E+01	7.14E-02	0.092%
	^{90}Sr	1.80E-02	2.27E-04	1.23%
	^{238}Pu	1.20E-05	4.62E-06	38%
	$^{239/240}$Pu	5.58E-05	3.04E-05	53%
	^{237}Np	1.68E-06	1.79E-06	104%
	^{241}Am	4.11E-05	4.16E-05	99%
	^{99}Tc	1.95E-02	1.85E-02	93%

Values in brackets [ ] were ≥ the method detection limit but < the estimated quantitation method, with errors likely to exceed ±15%.

Batch contact tests were performed with the AW-105 tank waste at four Cs concentrations and four temperatures (13, 16, 25, and 35 °C), each at a phase ratio of 200 (liquid volume to dry CST mass). The 16 °C distribution coefficient (K_d) at the equilibrium condition of 4.08E-5 M Cs (AW-105 feed condition) was 968 mL AW-105/g CST. With a CST bed density of 1.00 g/mL (<30 mesh CST), this K_d corresponded to a predicted 50% Cs breakthrough of 968 BVs. The observed column performance 50% Cs breakthrough (1041 BVs) fell within 7% of the predicted performance from batch contacts. The batch contact testing predicted a Cs load capacity of 0.0394 mmoles Cs/g dry CST at the equilibrium Cs concentration. The Cs breakthrough from the lead column at the 50% breakthrough point was used to determine full loading onto the CST at 100% C/C_0 and resulted in 0.0424 mmoles Cs/ g CST – 107.6% of the maximum Cs loading at feed condition based on prediction from batch contact testing.

Acknowledgements

The authors thank Hanford Tank Waste Operations and Closure for funding this work as well as Shielded Facility Operations staff Victor Aguilar for hot cell operations. We thank the Analytical Support Operations staff Steven Baum, Leah Arrigo, Christian Perez, and Dave Blanchard for the sample analysis, data processing, and reporting. The authors thank Heather Colburn, Christian Alvarez, and Renee Russell for conducting the technical reviews of the calculation files and this report. The authors also thank David MacPherson for the quality review of the calculation files and Alyssa Petersen for the quality review of this report as well as Matt Wilburn for his technical editing contribution to this report.

Acronyms and Abbreviations

AMPS	Advanced Modular Pretreatment System
ASO	Analytical Support Operations
ASR	Analytical Service Request
BV	bed volume
CST	crystalline silicotitanate
DF	decontamination factor
DFLAW	Direct Feed Low-Activity Waste
DI	deionized
DOE	U.S. Department of Energy
EQL	estimated quantitation limit
erf	error function
FD	feed displacement
GEA	gamma energy analysis
H2C	Hanford Tank Waste Operations and Closure
IC	ion chromatography
ICP-MS	inductively coupled plasma mass spectrometry
ICP-OES	inductively coupled plasma optical emission spectroscopy
ID	identification
IX	ion exchange
LAW	low-activity waste
MDL	method detection limit
NA	not applicable
NQAP	Nuclear Quality Assurance Program
PNNL	Pacific Northwest National Laboratory
SRF	spherical resorcinol-formaldehyde
TIC	total inorganic carbon
TOC	total organic carbon
TSCR	Tank Side Cesium Removal
WAC	waste acceptance criteria
WRPS	Washington River Protection Solutions
WTP	Hanford Waste Treatment and Immobilization Plant

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1.0 Introduction

Hanford Tank Waste Operations and Closure (H2C) is the tank operations contractor for the U.S. Department of Energy (DOE) Hanford Field Office on the Hanford Site. The Hanford Site stores an estimated 56 million gallons of mixed radioactive and chemically hazardous waste in large underground tanks. In support of the Direct Feed Low-Activity Waste (DFLAW) Program, DOE deployed a strategy to pretreat supernate waste at tank farms and send it directly to the Hanford Waste Treatment and Immobilization Plant (WTP) Low-Activity Waste (LAW) Facility for vitrification. To accommodate this strategy, DOE and H2C developed a two-phased approach. The first phase consisted of the deployment of a Tank Side Cesium Removal (TSCR) system located at AP Farm as a part of the TSCR Demonstration Project, which began operations in January 2022. This system provides the initial feed for hot commissioning of the LAW Facility. The second phase will consist of the deployment of a higher capacity pretreatment system – called the Advanced Modular Pretreatment System (AMPS) – that can deliver sufficient feed for two melters in the LAW Facility. Decanted tank waste supernate will be pretreated using AMPS to meet the LAW Facility waste acceptance criteria (WAC). Specific to ^{137}Cs, this requirement is <3.18E-5 Ci ^{137}Cs/mole of Na.[2]

In support of flowsheet planning, laboratory-scale ion exchange (IX) processing using 9.2 L of AW-105 tank waste was conducted to help understand the impact of a higher potassium (0.6 M K) but lower NO_3 tank composition on Cs and Sr removal by crystalline silicotitanate (CST). Although AW-105 is currently not identified as a direct feed to TSCR/AMPS, an understanding the expected filtration and IX performance is needed to assess processing viability, blending options, and other treatment strategies. The primary objective of the work described in this report was to test Cs removal from AW-105 using the current TSCR prototypic hybrid column processing at an operating temperature of 16 °C and establish Cs load profiles. For this testing, a lead-lag column system was used initially, but once the lag column effluent reached the WAC limit, a polish column was added after the lag column and processing continued in a lead-lag-polish configuration. Additional objectives of the current study were as follows:

1. Conduct batch contact testing with CST at 13, 16, 25, and 35 °C to determine the Cs load capacity of post-IX AW-105.
2. Conduct batch contact testing with CST at 25 °C to determine the Cs load capacity of pre-IX AW-105 and how it compares to batch contact results of AW-105 effluent that has passed through CST columns.
3. Compare the 16 °C AW-105 Cs load profile to the previously reported 16 °C AP-107, AP-101, and AP-105 load curves (Westesen et al. 2021, 2022, 2023).
4. Analyze the AW-105 IX feed and effluent to derive the fates of key analytes and radionuclides.
5. Assess potential precipitation of AW-105 by decreasing the temperature of the IX effluent to 10 °C.
6. Provide Cs-decontaminated AW-105 for vitrification (addressed in a separate report).

H2C funded Pacific Northwest National Laboratory (PNNL) to conduct testing with AW-105 tank waste under the Washington River Protection Solutions (WRPS) statement of work *Rad Waste Test Platform (RWTP) Processing of AW-105 Sample,* Rev. 1, Requisition 374236, dated October 2, 2024. There are no deviations from the statement of work.

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[2] 24590-WTP-ICD-MG-01-030, Rev. 1. 2021. *ICD 30 – Interface Control Document for Direct LAW Feed.* Bechtel National, Inc., Richland, Washington.

2.0 Quality Assurance

This work was conducted with funding from H2C under requisition 374236, *Rad Waste Test Platform (RWTP) Processing of AW-105 Sample*. This work was performed in accordance with the PNNL Nuclear Quality Assurance Program (NQAP). The NQAP complies with 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 Applications*, as its consensus standard and NQA-1-2012, Subpart 4.2.1, as the basis for its graded approach to quality. The data associated with this report was collected under technology readiness level 5, the highest level of applied research under NQAP.

3.0 Test Conditions

This section describes the CST media, AW-105 tank waste, column IX conditions, sample analysis, and batch contact conditions. All testing was conducted in accordance with a task plan prepared by PNNL and approved by H2C.[3]

3.1 CST Media

The CST used in this testing was procured by WRPS as ten 5-gallon buckets (149 kg total) of IONSIV R9140-B,[4] lot number 2002009604, from Honeywell UOP, LLC. The CST was transferred to PNNL for use in laboratory testing described herein. Details of the procurement and material properties can be found elsewhere (Fiskum et al. 2019a). Before use in column and batch contact testing, the CST was sieved to <30-mesh and pretreated by contacting with 0.1 M NaOH successively until fines were no longer observed. The <30-mesh CST sieve cut has been shown to provide appropriate performance scaling to a full-height TSCR column (Westesen et al. 2020).

3.2 AW-105 Tank Waste Sample

H2C collected multiple samples (36 at nominally 250 mL each) from Hanford tank AW-105 in October 2024. The first and last samples collected, 5AW-24-01 and 5AW-24-36, were subsampled for a limited analysis suite to confirm Na concentration, density, total inorganic carbon (TIC), total organic carbon (TOC), ion chromatography (IC), and Cs concentrations. The density was measured in a PNNL hot cell using a 10-mL volumetric flask. Analytical results are provided in Table 3.1. The results of the two samples agreed well, indicating the 36 samples were likely homogenous.

Table 3.1. Characterization of Samples 5AW-24-01 and 5AW-24-36

Analyte	5AW-24-01 Result	5AW-24-36 Result	Result Units	Analysis Method
TIC	0.523	0.549	M	Hot persulfate
TOC	0.098	0.106	M	Hot persulfate
Cl^-	0.036	0.036	M	IC
F^-	0.053	0.054	M	IC
NO_3^-	1.158	1.174	M	IC
NO_2^-	0.698	0.711	M	IC
PO_4^{3-}	0.010	0.010	M	IC
SO_4^{2-}	0.029	0.029	M	IC
Total Cs	4.74E-05	4.71E-05	M	ICP-MS
^{137}Cs	89.8(a)	90.5(a)	µCi/mL	GEA
Density	1.300(b)	1.302(b)	g/mL	Volumetric flask

(a) Reference date is October 22, 2024.
(b) Measured at 25.1 °C using a 10-mL volumetric flask.
Complete analytical reports are provided in Appendix B.
GEA = gamma energy analysis; ICP-MS = inductively coupled plasma mass spectrometry

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[3] Westesen AM. 2024. Task Plan DFTP-TP-179, Rev. 0.0. *FY25 Cesium Ion Exchange Testing with AW-105 Tank Waste Using Crystalline Silicotitanate Media.* Pacific Northwest National Laboratory, Richland, Washington. Not publicly available.

[4] R9140-B is provided in the sodium form by the vendor.

The Cs isotopic composition of the samples was measured to determine the total Cs concentration in the AW-105 tank waste. Except for ^{133}Cs, direct analysis of AW-105 waste for the ^{135}Cs and ^{137}Cs isotopes can result in isobaric interferences. Therefore, subsamples (first and last AW-105 tank samples collected, 5AW-24-01 and 5AW-24-36) were processed to isolate Cs. Aliquots (1.5 mL) of AW-105 were batch contacted with 2 mL Na-form spherical resorcinol-formaldehyde (SRF) resin suspended in 8 mL of 1 M NaOH. The slurries were mixed for ~24 hours on a shaker at room temperature. The aqueous phase was decanted and the SRF was washed three times with 6 mL of 0.1 M NaOH, then rinsed three times with 6 mL of deionized (DI) water. Cs was eluted from the SRF resin with 0.45 M HNO_3. Quantitative recovery was not required because only the Cs isotope ratios were needed, and isotope fractionation does not occur in Cs uptake to, or elution from, SRF resin. The elution aliquots were measured by ICP-MS for Cs isotopic distribution; results are presented in Table 3.2. The total Cs concentration was calculated from the GEA-measured ^{137}Cs and the ICP-MS-measured isotopic composition.

Table 3.2. 5AW-24-01 and 5AW-24-36 Average Cs Isotopic Composition (ASR 2163)

Analyte[(a)]	5AW-24-01 Results	5AW-24-36 Results	Units
Cs isotopic mass ratio[(a,b,c)]	66.1	66.0	wt% ^{133}Cs
	17.6	17.6	wt% ^{135}Cs
	16.3	16.4	wt% ^{137}Cs
Total Cs	6.33		µg/mL Cs

(a) The Cs eluate samples (5AW-24-01-Cs and 5AW-24-36-Cs) were analyzed for Cs isotopic mass distribution by ICP-MS per ASR 2163 samples 25-0040 and 25-0041; see Appendix B.
(b) Reference date is November 14, 2024.
(c) ^{134}Cs, a fission product, was not detected by GEA; with a 2.065-year half-life, it was assumed to be decayed to extinction.
ASR = Analytical Service Request

The AW-105 tank waste samples (also referred to herein as simply AW-105) were composited and diluted to achieve a targeted 1.25 g/mL density and 5.50 M Na concentration as described in Allred et al. (2025). Nominally, 0.158 L of Columbia River process water was combined for every 1 L of AW-105 tank waste. The AW-105 and water were mixed, and density was measured to verify that the target dilution had been achieved. Density was measured via 10-mL Class A volumetric flask and an analytical balance and was recorded at 1.2778 g/mL at an ambient cell temperature of 23.7 °C. The Na concentration was not measured after dilution but was measured after filtration (which should not affect Na concentration). The diluted AW-105 sample was chilled to 16 °C before being filtered with a media grade 5 filter (Allred et al. 2025). After filtration, eight bottles of AW-105, containing nominally 1.2 L each, were made available for IX testing.

The densities and ^{137}Cs concentrations of each of the eight bottles of AW-105 were measured. The density average was 1.280 g/mL (0.15% relative standard deviation) and the ^{137}Cs average was 77.8 µCi/mL (2.9% relative standard deviation; reference date January 2025). Therefore, AW-105 feeds in all containers were considered uniform. The total Cs concentration for the diluted waste was calculated from the ^{137}Cs concentration (in terms of µg/mL with unit conversion per the specific activity) and ^{137}Cs mass fraction (average 16.4 wt%). The total Cs concentration in the diluted AW-105 was 5.46 µg/mL or 4.08E-5 M.

3.3 Ion Exchange Column Processing at 16 °C

This section describes the process conditions of the IX column system used for AW-105 testing. The preparations and column testing were conducted in accordance with a PNNL test instruction.[5]

3.3.1 Ion Exchange Column System

Figure 3.1 provides a schematic of the IX process system used for the AW-105 column testing. The columns were housed in a 12-inch × 6-inch × 15-inch (W×D×H) insulated box, previously used and described in Westesen et al. (2022). Heat exchange was conducted with ethylene glycol from a chilled circulating bath flowing through copper tubing on the inner panels of the box. The internal temperature was monitored with a thermocouple seated inside a vial of water adjacent to the columns.

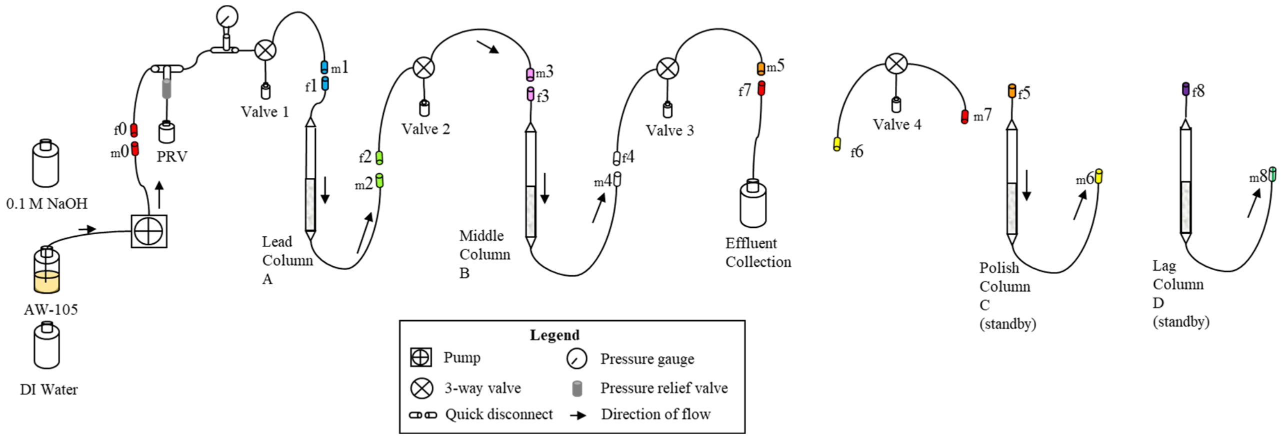

Figure 3.1. Schematic of the AW-105 Column System

Chromaflex column assemblies (previously described by Westesen et al. 2022) made of borosilicate glass measured 9 cm tall with an inside diameter of 1.5 cm (corresponding to a CST volume of 1.77 mL/cm) were used. The CST was supported by an in-house-constructed support consisting of a 200-mesh stainless steel screen tack welded onto a stainless-steel O-ring. The flared cavity at the bottom of each column was filled to the extent possible with 4-mm-diameter glass beads to minimize the mixing volume below the CST bed. An adhesive centimeter scale with 1-mm divisions (Oregon Rule Co., Oregon City, OR) was affixed to each column with the 0-point coincident with the top of the support screen.

Four Swagelok valves were installed on the valve manifold. Valve 1 was placed at the outlet of the pressure gage and used to isolate the columns from the pump (when in the closed position) and purge the tubing from the inlet to valve 1 (when placed in the sampling position). Lead column A samples were collected at valve 2, the lag column B samples were collected at valve 3, and the polish column C samples were collected at valve 4. A fourth column, D, was prepared in case the polish column reached the WAC before all the waste was processed, but was not needed in this testing. The gross AW-105 effluent, feed displacement (FD), water rinse, and flushed fluid were collected at the effluent line.

Aliquots of settled CST (pretreated, <30 mesh) were measured using a graduated cylinder and then quantitatively transferred to each individual column. Testing used 6.0-mL CST in each column. The CST was allowed to settle through the 0.1 M NaOH solution, thus mitigating gas bubble entrainment. The

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[5] Westesen AM. 2024. Test Instruction DFTP-TI-180. *Reduced Temperature Cesium Removal from AW-105 Using Crystalline Silicotitanate in a Two- and Three-Column Format.* Pacific Northwest National Laboratory, Richland, Washington. Implemented December 2024. Not publicly available.

columns were tapped with a rubber bung until the CST height no longer changed. The CST bed volume (BV) corresponded to the settled CST media volume as measured in the graduated cylinder prior to transferring the media to the IX column.

3.3.2 AW-105 Tank Waste Process Conditions

Once the IX columns were installed within the chiller box, a flow of 0.1 M NaOH was used to verify system integrity and calibrate the pump. The diluted and filtered AW-105 contained in multiple 1.5-L polyethylene containers was used as the IX feed. When the contents in a feed bottle decreased to ~300 mL, the next bottle in line was moved to the feed position and the residual contents were poured into the now primary feed bottle. The AW-105 feed was processed downflow through the IX media beds, lead to lag. Effluent was collected in ~1.5-L increments. The lag column effluent Cs concentration was closely monitored. When the WAC limit was reached, the polish column was placed in-line and the run continued.

After the AW-105 processing (also referred to as “loading” in subsequent discussion) was completed, ~12 BVs (72 mL) of 0.1 M NaOH FD followed by ~12 BVs of DI water were passed downflow through the system to rinse residual feed out of the columns and process lines. Figure 3.2 presents daily temperature and flowrate profiles of the AW-105 processing as it went through the columns. Temperature was measured using a thermocouple placed inside a vial of water within the exchanger. The exchanger temperature averaged 16.1 °C throughout the testing, with min/max temperatures of 15.2 and 17.2 °C, respectively. The length of the pump head stroke was close to the minimum at which it could be set. The stroke rate was adjusted throughout testing to maintain the flowrate between 1.8 and 2.2 BV/h. Table 3.3 summarizes the test parameters, including process volumes, flowrates, and CST contact times.

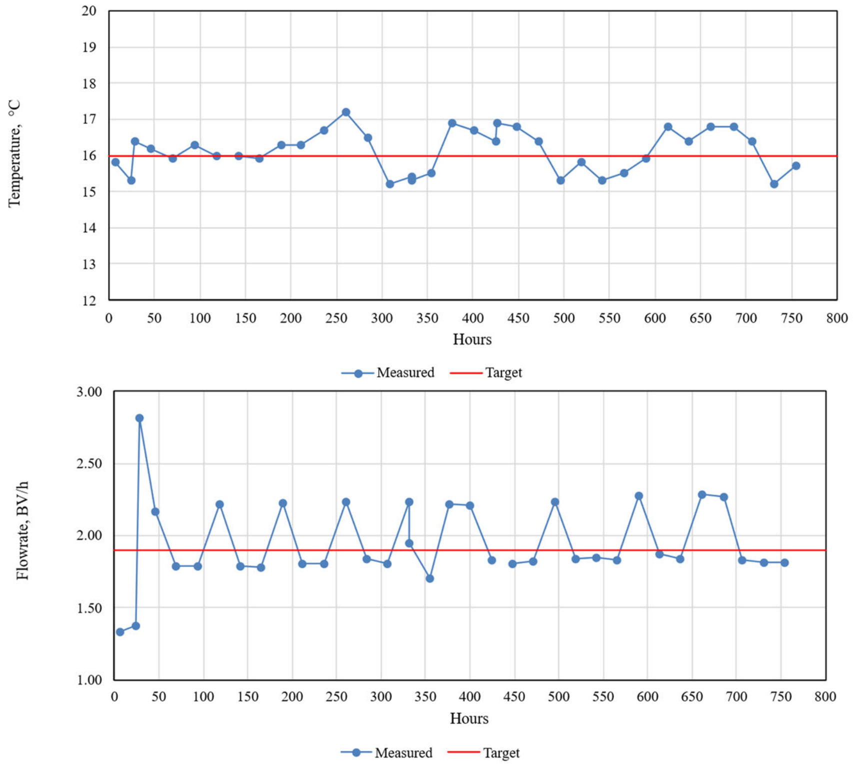

Figure 3.2. AW-105 Daily Column Temperature and Flowrate during Testing

Table 3.3. Experimental Conditions for AW-105 Column Processing at 16 °C, January 15 through February 17, 2025

Process Step	Solution	Volume (BV)	Volume (mL)	Flowrate (BV/h)	Flowrate (mL/min)	Duration (h)
Loading lead column	AW-105	1522.5	9135	1.95	0.195	790:43
Loading lag column[(a)]	AW-105	1515.2	9091	1.95	0.195	790:43
Loading polish column[(b)]	AW-105	832.9	4997.3	1.95	0.195	333:11
Feed displacement	0.1 M NaOH	12.8	77.0	3.14	0.314	4:05
Water rinse	DI water	18.2	108.9	3.03	0.303	5:59
Flush with compressed air	NA	9.9	59.2	NA	NA	NA

(a) The feed volume through the lag column was reduced relative to that of the lead column because samples collected from the lead column did not enter the lag column.

(b) The feed volume through the polish column was lower relative to that of the lead and lag columns because it was placed in position after 673 BVs were processed.

BV = bed volume (6.0 mL as measured in graduated cylinder); NA = not applicable.

The total cumulative volume of AW-105 processed was 9.0 L (1501 BVs). The process cycle mimicked, as best as possible, the process flow to be experienced at the TSCR facility in terms of Na concentration, BV/h (i.e., contact time), FD, and water rinse. It was understood that the feed linear flow velocity in this small-column configuration (0.17 cm/min) could not begin to match that of the full-height processing configuration (7.3 cm/min; Fiskum et al. 2019a). The objective was to match contact time in the bed.

During the loading phase, nominal 2-mL samples were collected from the lead, lag, and polish columns at the sample collection ports (see Figure 3.1, valves 2, 3, and 4). Sampling from the columns necessitated brief (~10-minute) interruptions of flow to the downstream columns. Samples were collected after the first 11 BVs were processed and again at nominal 15- to 150-BV increments. Only brief (~3-minute) interruptions were associated with changing the feed bottles.

The FD effluent was collected in bulk in a 125-mL polyethylene bottle. The water rinse was similarly collected. The fluid-filled volume was expelled with compressed air in ~4 minutes. The collected volume (~60 mL) did include the interstitial fluid space between the CST beads but was not expected to include fluid in the CST pore space. Hours of additional gas flow were required to dry the CST enough to be free flowing.

3.4 Batch Contact Conditions

Batch contact experiments with the pre- and post-IX AW-105 were conducted to evaluate Cs loading before and after any competitor anions were removed from column testing. Additional tests at four different temperatures were conducted with the post-IX AW-105 effluent. Stock solutions of 0.75 and 0.084 M $CsNO_3$ were prepared by dissolving the nitrate salt in a volumetric flask and diluting with DI water. Calculated volumes of Cs stock solutions were delivered to poly bottles, and the mass of the spike was measured. The diluted AW-105 was spiked with ^{137}Cs and AW-105 was transferred into each poly bottle to achieve Cs concentrations of 5.5, 20, 60, 200, and 2000 mg/L. Solutions were prepared gravimetrically, and exact volumes were calculated from mass and density measurements.

Nominal 0.075-g (dry mass basis) aliquots of CST were measured into 20-mL vials. F-factor samples were collected in duplicate, bracketing batch contact aliquots, and used to determine the dry mass of the exchanger. The F-factor was measured at 105 °C with an average value of 0.948. The F-factor at 105 °C measured at the time of the experiment was used to calculate the dry mass of CST for the AW-105 batch contact tests.

Aliquots (15-mL) of the AW-105 Cs stock solutions were added to the appropriate vials (in duplicate) and the exact solution volume transferred was calculated from net solution mass and density. The solution-to-mass phase ratio averaged 193.3 ± 1.8 mL/g.

Batch contacts on the pre-IX AW-105 were conducted in the hot cell at ambient cell conditions (~25 °C). Post-IX AW-105 effluent tests were conducted at 13, 16, 25, and 35 °C. For the post-IX AW-105 effluent tests, two batch contact tests were conducted in series, where 13 and 25 °C samples were tested concurrently, followed by concurrent testing of the 16 and 35 °C samples. The lower temperature samples (13 and 16 °C) were contacted on a refrigerated/heated Benchmark (Sayreville, New Jersey) Incu-Shaker orbital shaker and the higher temperatures (25 and 35 °C) were contacted on a Benchmark Incu-Shaker10LR. All samples were contacted at 200 rpm. A vial of water co-located with each sample set was used to monitor the temperature over the ~120-hour contact time. Figure 3.3 shows the resulting temperature fluctuations with error bars representative of the 2.2 °C measurement uncertainty of a Type K thermocouple. Table 3.4 presents the weighted mean temperature for each set of batch contacts.

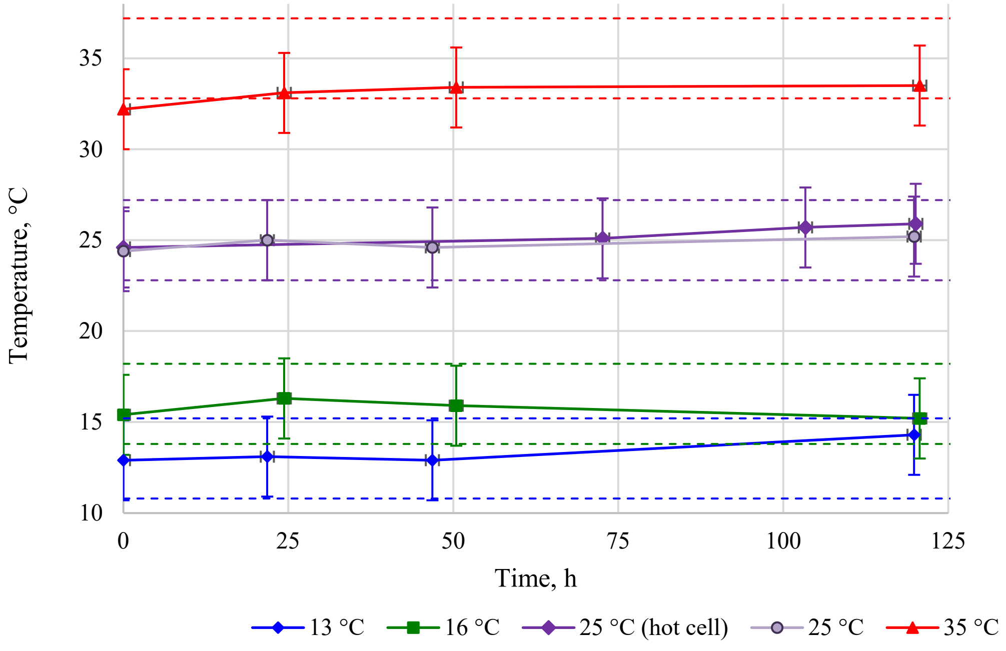

Figure 3.3. Temperature Profiles of Batch Contact Testing with AW-105 Tank Waste Supernate

Table 3.4. Average Contact Temperature

Target Temperature (°C)	Weighted Mean Temperature (°C)
13	13.4
16	15.7
25	24.8
25 (hotcell)	25.1
35	33.2

After contact, 2 mL of the supernate was removed and filtered through a 0.45-micron pore size nylon syringe filter and transferred to a glass vial for GEA. The ^{137}Cs activity measured by GEA in pre- and post-contacted solutions was used to determine the total Cs exchange. Analysis and data reduction were conducted using the methods previously reported (Fiskum et al. 2019b). The isotherm data were fitted to a Freundlich/Langmuir hybrid equilibrium fit (Hamm et al. 2002).

The batch distribution coefficients were calculated according to Eq (3.1):

$$\frac{(A_0 - A_1)}{A_1} \times \frac{V}{M \times F} = K_d \tag{3.1}$$

where:

A_0 = initial ^{137}Cs concentration (µCi/mL)
A_1 = final (equilibrium) ^{137}Cs concentration (µCi/mL)
V = volume of the batch contact liquid (mL)
M = measured mass of CST (g)
F = F-factor, mass of the 105 °C dried CST divided by the mass of the undried CST
K_d = batch-distribution coefficient (mL/g)

Final (equilibrium) Cs concentrations (C_{Eq}) were calculated relative to the tracer recovered in the contacted samples (A_1) and the initial metal concentration (C_0) according to Eq. (3.2):

$$C_0 \times \left(\frac{A_1}{A_0}\right) = C_{Eq} \tag{3.2}$$

where:

C_0 = initial Cs concentration in solution (µg/mL or M)
C_{Eq} = equilibrium Cs concentration in solution (µg/mL or M)

The equilibrium Cs concentrations loaded onto the CST (Q in units of mmoles Cs per gram of dry CST mass) were calculated according to Eq. (3.3):

$$\frac{C_0 \times V \times \left(1 - \frac{A_1}{A_0}\right)}{M \times F \times 1000 \times FW} = Q \tag{3.3}$$

where:

Q = equilibrium Cs concentration in the CST (mmole/g CST)
1000 = conversion factor to convert µg to mg
FW = Cs formula weight

3.5 Chilled AW-105 Supernate Precipitation

An assessment of potential supernate precipitation with chilled temperatures was conducted on the AW-105 effluent samples post column processing. Cs-decontaminated AW-105 samples started at room temperature (~20 °C) and were cooled in increments of 3 °C down to 10 °C and a hold time of 24 hours at each temperature. Subsamples of the waste were collected and filtered at contact temperature to determine which (if any) solids precipitated. Samples were conducted in duplicate and demonstrated minor precipitation at 11 °C (see Figure 3.4). The chilled shaker was maxed out at 11 °C and could not be assessed at temperatures lower than that. There were not enough solids to collect and analyze on their own but the filtered supernate was analyzed for inductively coupled plasma optical emission spectroscopy

(ICP-OES) and compared to the pre-precipitated AW-105 effluent concentrations. Table 3.5 shows the difference in concentration for analytes whose recovery was <60% of the feed solution and indicated the precipitation appeared to be B and Si as they were present in the highest concentrations (0.03 and 0.08 M) by far of all the observed analytes removed. Suspected ions Al and P demonstrated 93% and 103% recoveries respectively, indicating no precipitation of those analytes.

Figure 3.4. Chilled AW-105 Precipitation at 11 °C

Table 3.5. Chilled Supernate Precipitation Results

Analyte	Pre-precipitated, M	Post-precipitated, M	Fraction Remaining
B	2.80E-02	1.15E-02	41%
Ba	1.74E-06	4.66E-07	27%
Co	1.26E-05	6.40E-06	51%
Mg	2.04E-05	1.24E-05	61%
Ru	5.94E-05	3.44E-05	58%
Si	7.87E-02	5.84E-03	7%
Sr	3.73E-07	1.67E-07	45%
Th	5.20E-06	2.06E-06	40%
Ti	2.23E-05	8.70E-06	39%

3.6 Sample Analysis

Cesium load performance was determined from the ^{137}Cs measured in the collected samples relative to the native ^{137}Cs in the AW-105 feed. The collected samples were analyzed directly to determine the ^{137}Cs concentration using GEA. Cesium loading breakthrough curves for the lead, lag, and polish columns were generated based on the feed ^{137}Cs concentration (C_0) and the effluent Cs concentration (C) in terms of % C/C_0.

A composite feed sample for the as-received and diluted AW-105 feed was prepared by collecting a pro-rated volume from each feed bottle and combining in a polyethylene vial; a composite effluent sample was similarly collected. Table 3.6 summarizes the specific sample collections and targeted analytes along with a cross-reference to the analytical sample identification (ID).

Analytical services were responsible for the preparation and analysis of appropriate analytical batch and instrument quality control samples and for providing any additional processing to the sub-samples that might be required (e.g., acid digestion, radiochemical separations, dilutions). All analyses were conducted according to the analytical services standard operating procedures, the quality assurance plan, and the ASR. Samples were analyzed directly (no preparation) by GEA; longer count times were used to assess isotopes other than ^{137}Cs.

Table 3.6. Analytical Scope Supporting AW-105 Column Processing

Sample ID	Analytical ID	Analysis Scope
As-received AW-105	ASO: 25-0038 through 25-0043	GEA (^{241}Am, ^{137}Cs, ^{60}Co) OH^- ICP-MS (^{133}Cs, ^{135}Cs, ^{137}Cs) ICP-OES (Al, As, Ba, Ca, Cd, Cr, Fe, K, Na, Ni, P, Pb, S, Sr, Ti, U, Zn, Zr)
	331: 2411017-01 and -02	IC anions (F^-, Cl^-, NO_2^-, NO_3^-, PO_4^{3-}, $C_2O_4^{2-}$, SO_4^{2-}) TIC/TOC
AW-105 IX feed	ASO: 25-0752	GEA (^{241}Am, ^{137}Cs, ^{60}Co, ^{154}Eu) OH^- IC anions (F^-, Cl^-, NO_2^-, NO_3^-, PO_4^{3-}, $C_2O_4^{2-}$, SO_4^{2-}) TIC/TOC ^{99}Tc ^{90}Sr AEA for ^{237}Np, ^{238}Pu, $^{239+240}$Pu, ^{241}Am ICP-OES (Al, As, Ba, Ca, Cd, Cr, Fe, K, Na, Ni, P, Pb, S, Sr, Ti, U, Zn, Zr)
AW-105 IX effluent	ASO: 25-0753	GEA (^{241}Am, ^{137}Cs, ^{60}Co, ^{154}Eu) OH^- IC anions (F^-, Cl^-, NO_2^-, NO_3^-, PO_4^{3-}, $C_2O_4^{2-}$, SO_4^{2-}) TIC/TOC ^{99}Tc ^{90}Sr AEA for ^{237}Np, ^{238}Pu, $^{239+240}$Pu, ^{241}Am ICP-OES (Al, As, Ba, Ca, Cd, Cr, Fe, K, Na, Ni, P, Pb, S, Sr, Ti, U, Zn, Zr)

AEA = alpha energy analysis

4.0 Results

This section discusses the Cs exchange behavior during batch contact and column testing with AW-105 tank waste. IX process raw data are provided in Appendix A. Batch contact raw data are provided in Appendix C.

4.1 Ion Exchange Processing

The Cs load behavior for AW-105 tank waste was evaluated at 16 °C. This section discusses the Cs load behavior for the executed test.

4.1.1 Cs Load Results

The diluted and filtered AW-105 was processed at nominally 1.95 BV/h through the lead and lag columns for 673 BVs, at which time the lag column effluent approached the WAC limit. The polish column was then placed into position and processing continued for another ~830 BVs. Figure 4.1 shows the Cs breakthrough profiles for the AW-105 columns using a probability log scale plot. The C_0 value for ^{137}Cs was determined to be 77.8 µCi/mL (average of the eight diluted and filtered IX feed bottles).

The Cs breakthrough from the lead column was observed to start at ~70 BVs and continued to 83% C/C_0 after processing 1522 BVs when the last sample was collected from the lead column. Similarly, the lag column Cs breakthrough appeared to start at ~300 BVs and increased to 14.1% when the last sample was collected from the column. Breakthrough on the polish column appeared instantaneously after installation around 700 BVs and reached 0.27% after the 832.9 BVs processed through it. In addition to the 50% C/C_0 indication line, the WAC limit, set at 0.225% C/C_0, is also apparent (dashed blue line).[6]

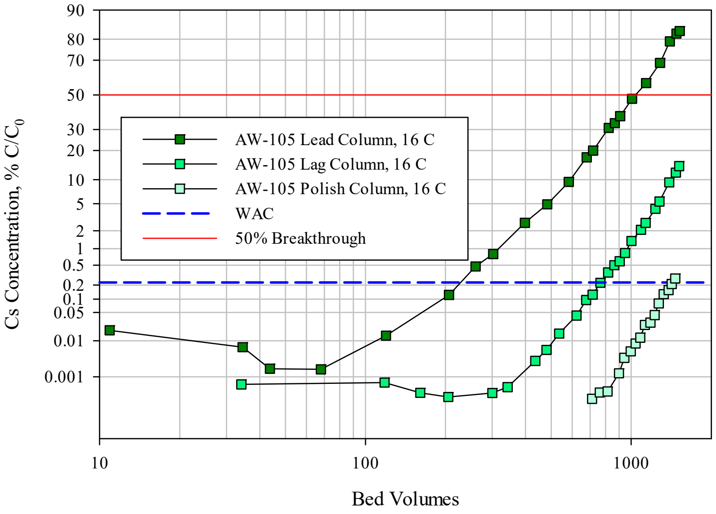

Figure 4.1. Lead, Lag, and Polish Column Cs Load Profiles of AW-105 at 1.9 BV/h

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[6] The WAC limit was derived from the allowed curies of ^{137}Cs per mole of Na in the effluent to support contact handling of the final vitrified waste form – 3.18E-5 Ci ^{137}Cs/mole Na. At 5.50 M Na and 77.8 µCi ^{137}Cs/mL in the AW-105 feed, the WAC limit is determined to be 0.225% C/C_0.

The Cs breakthrough curves were modeled by the error function (erf) (Hougen and Marshall 1947; Klinkenberg 1948), as shown in Eq. (4.1):

$$\frac{C}{C_0} = \frac{1}{2}\left(1 + \operatorname{erf}\left(\sqrt{k_1 t} - \sqrt{k_2 z}\right)\right) \tag{4.1}$$

where:

k_1 and k_2 = parameters dependent on column conditions and IX media performance
t = time (or BVs processed)
z = column length

Using this model, fits were generated to the AW-105 lead and lag column experimental data shown in Figure 4.2. The k1 and k2 values were 80.0 and 13.0, respectively, for AW-105 lead column and 78.3 and 26.7, respectively, for the lag column.

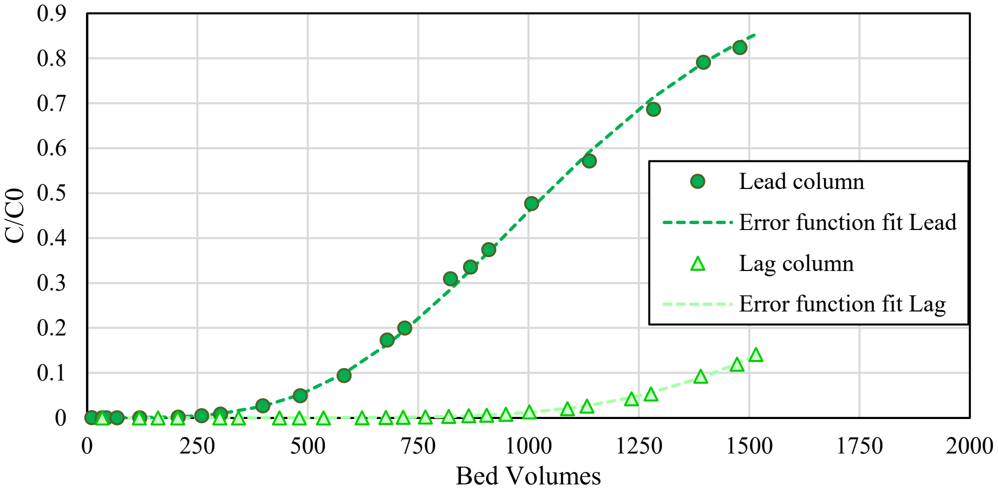

Figure 4.2. AW-105 Lead and Lag Column Cs Breakthrough with Error Function Fit

The 50% Cs breakthrough values for the lead and lag columns were estimated from the error function fit at 1041 and 2089 BVs, respectively. The theoretical 50% Cs breakthrough on the IX column (λ) can be predicted from the product of the K_d value and the ion exchanger bed density (ρ_b) according to Eq. (4.2) (Bray et al. 1993). The CST bed density is the dry CST mass divided by the volume in the column:

$$K_d \times \rho_b = \lambda \tag{4.2}$$

The lead column 50% Cs breakthrough value was within 1% of the Cs λ value predicted from the 16 °C batch contact studies (968 BVs as described in Section 4.2).

The WAC limit Cs breakthrough values were interpolated for each column by curve-fitting the BVs processed as a function of the log % C/C_0 values (see Figure 4.3). The curves were fitted to a second-order polynomial function ($R^2 \geq 0.99$) and the WAC limit breakthrough values were then calculated, resulting in the following:

- Lead column: 230 BVs
- Lag column: 772 BVs
- Polish column: 1426 BVs

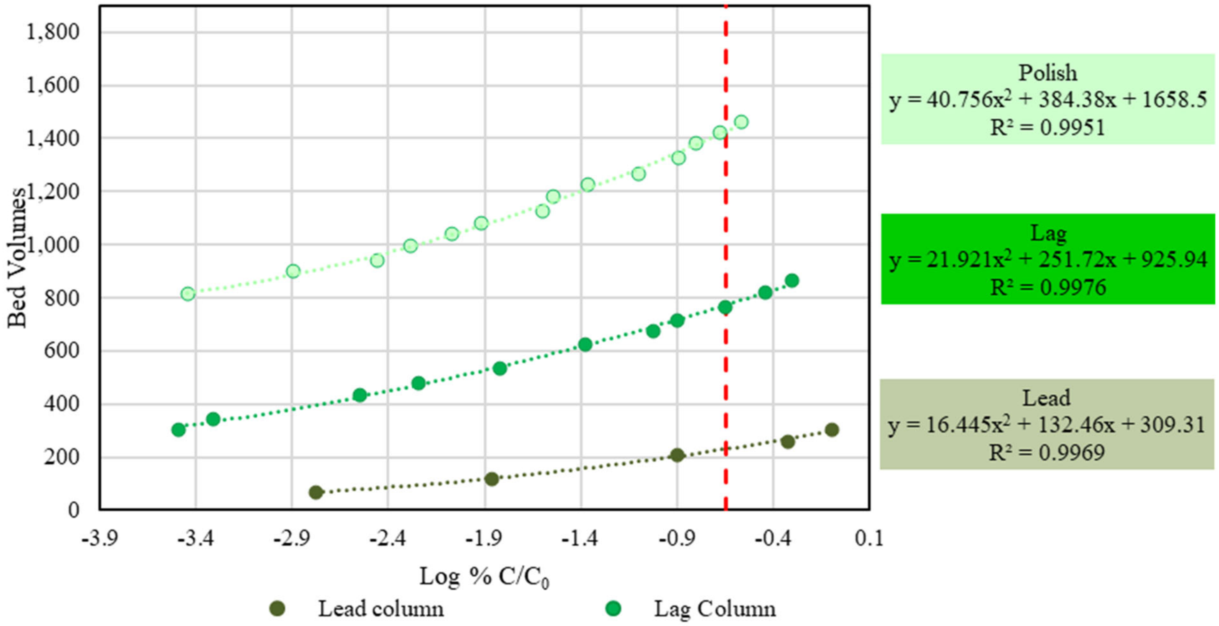

Figure 4.3. Curve Fits to Interpolate WAC Limit Breakthrough Values from AW-105 Lead, Lag, and Polish Columns

4.1.2 Cesium Activity Balance

The Cs fractionations to the effluents and the columns were determined based on the input ^{137}Cs and the measured ^{137}Cs in the various effluent streams. The quantities of Cs loaded onto the lead, lag, and polish columns were determined by subtracting the Cs recovered in the samples and effluents from the Cs fed to each column. Table 4.1 summarizes the ^{137}Cs fractions found in the various effluents as well as the calculated ^{137}Cs column loadings. Approximately 70.2 % of the total Cs loaded onto the lead column, 28.2% loaded onto the lag column, and only 1.5% loaded onto the polish column. Sample and effluent collection amounted to only ~0.16% of the input Cs.

Table 4.1. ^{137}Cs Activity Balance for AW-105

Input		
	μCi	%
Feed Sample	7.16E+05	100
Output		
Effluent-1 (0-204 BVs)	0.00	5.99E-07
Effluent-2 (204-433 BVs)	0.70	9.71E-05
Effluent-3 (433-619 BVs)	13.98	1.95E-03
Effluent-4 (619-814 BVs)	16.48	2.30E-03
Effluent-5 (814-994 BVs)	0.97	1.35E-04
Effluent-6 (994-1178 BVs)	9.5	1.32E-03
Effluent-7 (1178-1378 BVs)	61.05	8.53E-03
Effluent-8 (1378-1501 BVs)	105.44	1.47E-02
Load samples	1115	1.56E-01
Feed displacement, water rinse and flush	40.4	5.64E-03
Total ^{137}Cs recovered in effluents	1,363	1.91E-01
Total ^{137}Cs column loading		
Lead column Cs loading	5.02E+05	70.2
Middle column Cs loading	2.02E+05	28.2
Polish column Cs loading	1.07E+04	1.5
Column total	7.14E+05	99.8

The total Cs loaded per g CST was calculated from the total Cs loaded onto the lead column and the dry CST mass loaded into the lead column according to Eq. (4.3):

$$\frac{A_{Cs} \times CF}{M} = C \tag{4.3}$$

Where:

A_{Cs} = activity of ^{137}Cs, μCi on the lead column
CF = conversion factor, mg Cs/μCi ^{137}Cs
M = mass of dry CST (6.0 g)
C = capacity, mg Cs/g CST

A total of 5.88 mg Cs/g CST (0.0439 mmoles Cs/g CST) was loaded onto the lead column and was notably lower than previous AP-101, AP-107, and AP-105 testing at 16 °C (see Table 4.2), likely a direct result of the increased K concentration (described further in Sections 4.1.4 and 4.2.2). Since 50% breakthrough on the lead column was calculated per Eq. (4.2), the total load capacity was determined and was calculated to be 5.69 mg Cs/g CST (0.0424 mmoles Cs/g CST). This represented 107.6% of the predicted Cs load capacity found from batch contact testing (see Section 4.2.1) and shows good agreement between batch contacts and column flowthrough measurements.

Table 4.2. AW-105 Cs CST Column Loading Comparison

Test	Sieve Fraction	CST Cs loading (mg Cs/g CST)	Reference
AW-105, 16 °C	<30 mesh	5.88	Current report
AP-105, 16 °C	<30 mesh	7.38	Westesen et al. (2023)
AP-101, 16 °C	<30 mesh	7.31	Westesen et al. (2022)
AP-107, 16 °C	<30 mesh	7.08	Westesen et al. (2021)

4.1.3 AW-105 Performance Comparison

Figure 4.4 presents the AW-105 and previously processed lab-scale AP-107 (Westesen et al. 2021) and actual AP-107 TSCR Batch 1 column load profiles on one graph for direct comparison. Testing parameters for the three tank wastes are shown in Table 4.3. The Cs exchange associated with AW-105 resulted in the same number of BVs processed to reach the WAC on the lead column as AP-107. Initially perplexing due to the increased K concentration in AW-105, analysis of the feed indicated notably lower concentrations of NO_3 and NO_2 (which have been shown to negatively impact Cs removal with increasing concentration). It appears this change in matrix offsets the negative impact from the increased concentration of K. For the lag and polish columns, AW-105 reached the WAC slightly earlier than AP-107. Also seen when comparing the data sets is a slightly steeper slope in breakthrough curves for the AW-105, indicating faster kinetic exchange onto the CST. This could be due to slight temperature variations between the tests or matrix impacts from the different waste streams. Comparing the 50% breakthrough point showed a nominal 4% decrease in capacity for the AW-105 waste (1041 BVs to 50% breakthrough for AW-105 and 1087 BVs to 50% breakthrough for AP-107), further indicating the offset in performance by the decreased NO_3 and NO_2 concentrations relative to the increased K concentration.

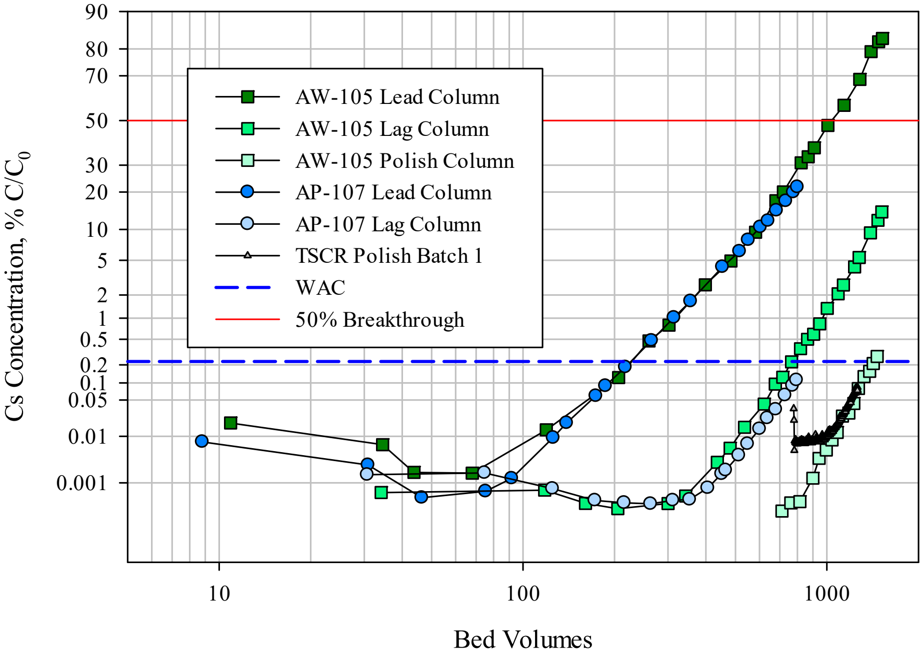

Figure 4.4. Comparative Cs Breakthrough Performance for AW-105, AP-107, and TSCR AP-107 Probability-Log Plot

Table 4.3. AW-105, AP-107 and AP-101 at 16 °C Testing Parameters

Testing Condition	AW-105 (Current)	AP-107 (FY21)	AP-107 (TSCR)
Configuration	Lead-Lag-Polish	Lead-Lag	Lead-Lag-Polish
Flowrate, BV/h	1.94	1.92	~1.9
Process temp. °C	16.0	16.0	~20
Density, g/mL	1.280	1.271	1.271
WAC limit, %C/C_0	0.147	0.114	0.114
Lag column BVs to WAC	772	791	--
Cs, M	4.08E-05	6.99E-05	6.99E-05
Na, M	5.6	6.20	6.20
K, M	0.58	0.10	0.10
NO_3, M	1.32	1.85	1.85
NO_2, M	0.77	1.22	1.22

4.1.4 Metals and Radionuclide Analysis

The AW-105 composite feed and composite effluent samples underwent extensive characterization to better define waste characteristics and assess analyte fractionation to the CST.

Table 4.4 summarizes the feed and effluent radionuclide concentrations and fractionations to the effluent. Partitioning to the effluent was only determined for ^{137}Cs by GEA due to higher concentrations measured in the effluent compared to the feed. Table 4.5 presents the concentrations of the metals, anions, free hydroxide, and inorganic and organic carbon. Analytical reports along with result uncertainties and quality control discussions are provided in Appendix B.

By inference, the analytes present in the feed and not found in the effluent were assumed to be retained on the CST. Analyte fractionation was calculated as the ratio of the total analyte measured in the feed processed through the columns to the total analyte collected in the Cs-decontaminated effluent according to Eq. (4.4):

$$\frac{C_{Da} \times V_D}{C_{Fa} \times V_F} = F_{Da} \tag{4.4}$$

where:

C_{Da} = concentration of analyte *a* in the Cs-decontaminated effluent
V_D = volume of Cs-decontaminated effluent
C_{Fa} = concentration of analyte *a* in the AW-105 feed
V_F = volume of AW-105 feed
F_{Da} = fraction of analyte *a* in the Cs-decontaminated effluent

The analyte results shown in brackets in Table 4.5 indicate that the result was less than the instrument estimated quantitation limit (EQL) but greater than or equal to the method detection limit (MDL); the associated analytical uncertainty could be higher than ±15%. The fractionation result was placed in brackets, where it was calculated with one or more bracketed analytical values to highlight the higher uncertainty.

Table 4.4. AW-105 Feed and Effluent Radionuclide Concentrations and Fractionations

Analysis Method	Radionuclide	Feed Conc. TI180-Comp-Feed (µCi/mL)	Effluent Conc. TI180-Comp-Eff (µCi/mL)	Fraction in Effluent (%)
Gamma energy analysis[(a)]	^{60}Co	1.55E-04	4.94E-04	--
	^{137}Cs	7.60E+01	7.14E-02	0.092%
	^{152}Eu	<6.0E-4	<4.4E-5	--
	^{154}Eu	<1.2E-3	7.48E-05	--
	^{155}Eu	<1.7E-2	<1.8E-4	--
	^{241}Am	<5.8E-2	<6.8E-4	--
Separations/ alpha energy analysis[(b)]	^{241}Am	4.11E-05	4.16E-05	99%
	^{237}Np	1.68E-06	1.79E-06	104%
	^{238}Pu	1.20E-05	4.62E-06	38%
	$^{239+240}$Pu	5.58E-05	3.04E-05	53%
Separations/ beta counting[(b)]	^{90}Sr	1.80E-02	2.27E-04	1.23%
	^{99}Tc	1.95E-02	1.85E-02	93%

(a) Reference date is February 2025.

(b) Reference date is June 2024.

"--" = not applicable; value not reported, or fractionation cannot be calculated with a less-than value.

The recovered fractions are calculated with values containing more significant figures than shown; using listed values may result in a slight difference due to rounding.

Table 4.5. AW-105 Feed and Effluent Concentrations and Fractionations

Analysis Method	Analyte	Feed Conc. TI180-Feed-Comp (M)	Effluent Conc. TI180-EFF-Comp (M)	Fraction in Effluent (%)
ICP-OES metals / non-metals	Al	3.17E-01	3.22E-01	99%
	Cr	6.22E-03	6.17E-03	97%
	Fe	[6.3E-05]	[7.4E-05]	115%
	K	5.81E-01	5.69E-01	96%
	Na	5.63E+00	5.56E+00	97%
	Ni	[9.5E-05]	[1.4E-04]	149%
	P	[1.3E-02]	[1.3E-02]	97%
	S	[4.2E-02]	[4.4E-02]	104%
	Ti	9.09E-06	[1.5E-05]	160%
	Zn	5.09E-04	[4.9E-04]	95%
	B	[5.9E-03]	[1.9E-03]	32%
	Be	2.03E-04	[1.9E-04]	93%
	Cu	[8.5E-05]	[8.2E-05]	94%
	Mn	[1.9E-05]	[1.7E-05]	91%
	Sn	5.50E-04	[6.3E-04]	112%
	W	[2.05E-04]	[2.5E-04]	121%
Ion chromatography anions	F^-	0.059	0.058	98%
	Cl^-	0.038	0.038	102%
	NO_2^-	0.773	0.774	100%
	NO_3^-	1.318	1.320	100%
	PO_4^{3-}	--	--	--
	SO_4^{2-}	0.028	0.028	101%
Titration	Free hydroxide	1.325	--	--
Hot persulfate oxidation	Total organic C	1.01E-01	1.03E-01	103%
	Total inorganic C(a)	6.19E-01	6.10E-01	98%

(a) Assumed to be carbonate.

Bracketed values indicate the associated sample results were less than the EQL but greater than or equal to the MDL. Analytical uncertainty for these analytes was > ±15%.

In addition to Cs removal, the CST removed 98.8% of the ^{90}Sr, with a ^{90}Sr decontamination factor of 81. Although this is a high removal percentage, it appears to be less than previous tank waste tests that removed > 99.9% of ^{90}Sr. It is possible that a change in Sr speciation is driving the removal capabilities in the waste stream, but this cannot be confirmed with current analysis techniques. Nominally all the Tc, Am, and Np partitioned to the effluent. About half of the Pu was removed by the CST, consistent with previous testing of tank waste.

The ICP-OES, IC, and carbon results for the feed and effluent composite showed that nearly all major analytes and anions remained in the effluent.

The load behaviors of selected analytes were examined as a function of BVs processed through the lead column. (Raw data are provided in Appendix B.) Figure 4.5 shows the ^{237}Np, ^{238}Pu, $^{239+240}$Pu, ^{241}Am, and ^{90}Sr breakthrough results along with the Cs breakthrough profile.

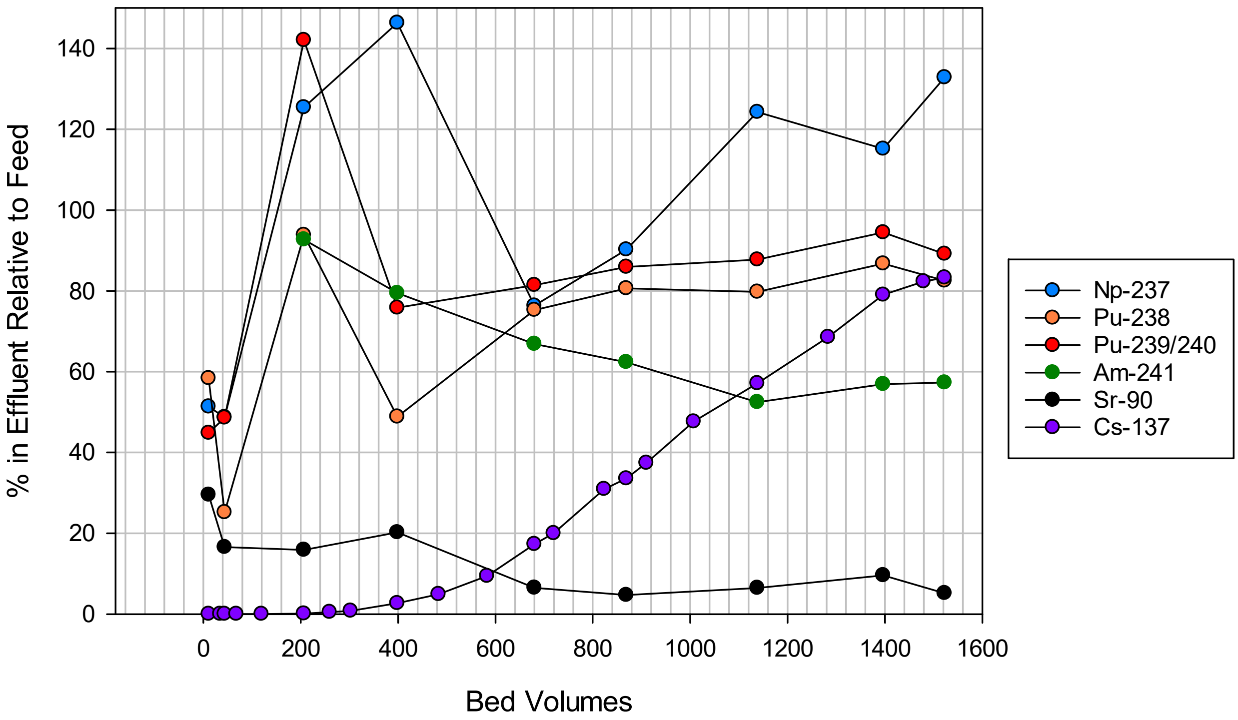

Figure 4.5. ^{137}Cs, ^{237}Np, ^{238}Pu, $^{239+240}$Pu, ^{241}Am, and ^{90}Sr Load Profiles from the Lead Column

Somewhat sporadic breakthrough was exhibited by ^{237}Np and ^{238}Pu (specifically around the 250 BV mark) but demonstrated that nominally 50% of these radionuclides are of a form that can be removed by the CST and indicated early saturation of the available forms of each analyte. A gradual breakthrough of $^{239+240}$Pu was seen from 55% to 10% removal by the CST over the duration of the BVs processed. A variation of oxidation states for Pu in the tank waste could be causing a complexation of soluble Pu that cannot be removed by CST.

Strontium breakthrough was observed immediately at 29% and slowly increased loading onto CST with increasing volume processed. The ^{90}Sr resulted in a fractional breakthrough of 5.2% after processing 1500 BVs. This breakthrough behavior is in contrast to past observations (Westesen et al. 2022), where the fraction removed by CST mimicked Cs behavior with breakthrough occurring over time.
The breakthrough data were used to construct a logarithmic probability plot of ^{90}Sr and ^{137}Cs breakthrough vs. column throughput, shown in Figure 4.6. Displaying the data in this way typically allows sorption ratios to be estimated, which are approximately equal to the number of BVs at 50% breakthrough. Although the ^{90}Sr breakthrough behavior observed in this testing does not allow for this estimation due to the increasing removal with BVs processed, it does highlight CST's selectivity for Sr over Cs.

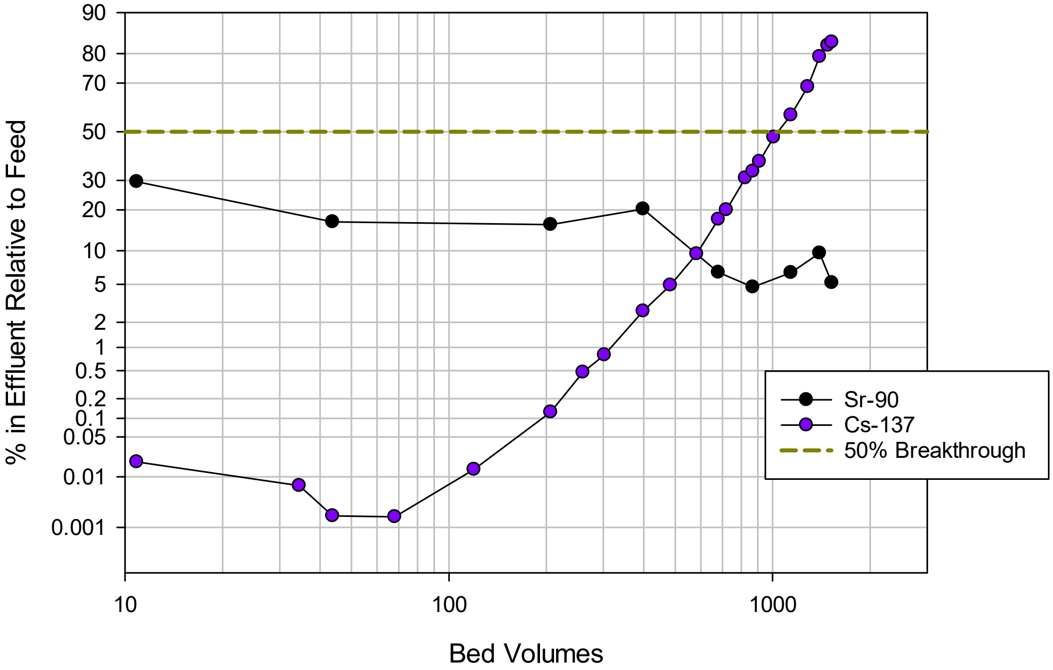

Figure 4.6. ^{90}Sr and ^{137}Cs Breakthrough Profiles

4.2 Batch Contact Results

This section provides the K_d and isotherm curves for AW-105 tank waste pre- and post-IX and at four test temperatures. Additionally, the data are compared to AN-107 variable K concentration capacity results. Appendix C presents input data supporting the various isotherms and figures.

4.2.1 K_d and Isotherm Results for AW-105

Figure 4.7 shows the K_d dependence on Cs concentration at target temperatures of 13, 16, 25, and 35 °C. The K_d increased with decreasing temperature, consistent with previous batch contact testing with AN-107, AP-105, AP-107 and AP-101 tank waste (Westesen et al. 2022, 2023, 2024; Fiskum et al. 2021). Interestingly, a distinguishable difference is seen in K_d values for the three lowest Cs concentrations measured (20, 60, and 200 µg/mL). This behavior is unique, as previous observations for AN-107, AP-107, AP-101, and AP-105 all showed that the K_d was not impacted by small changes in Cs concentrations of $<10^{-3}$ M Cs.

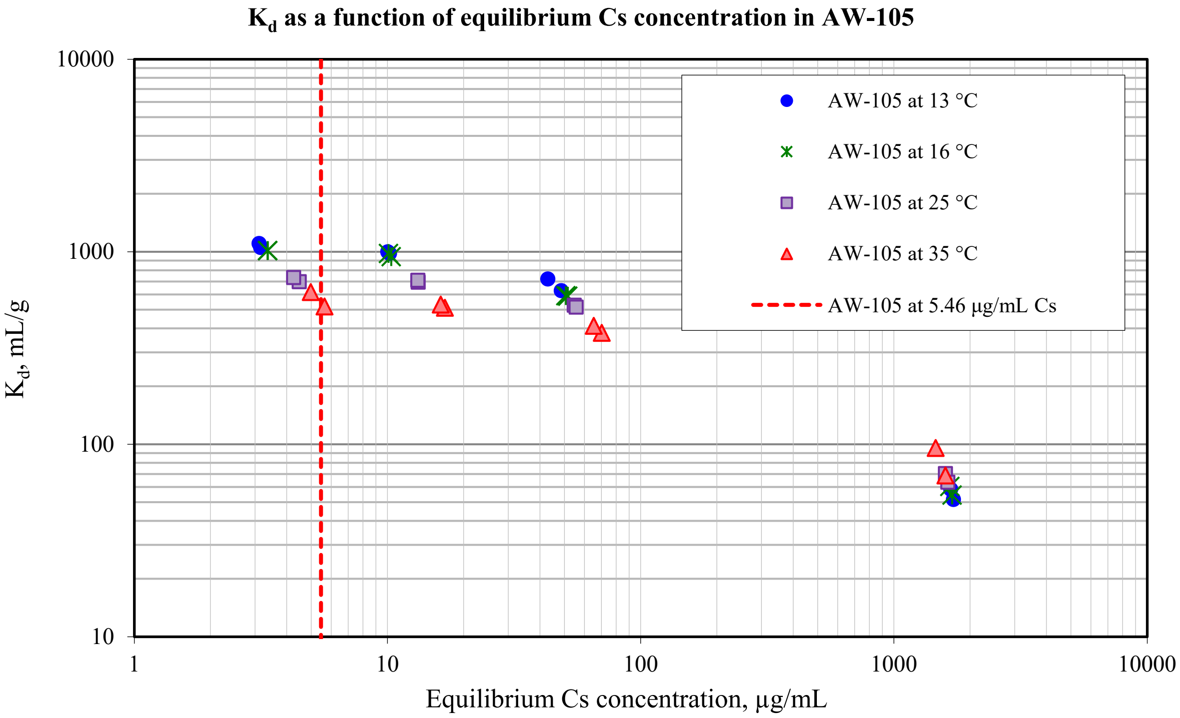

Figure 4.7. Cs K_d vs. Cs Concentration, AW-105 Tank Waste, Four Temperatures

Figure 4.8 shows the corresponding isotherms and Q (mmoles Cs/g dry CST) values vs. Cs molarity at all four test temperatures with AW-105 tank waste. It is important to note that the α_i, or total capacity in the matrix, was set to 0.68 mmoles Cs/g CST for this evolution of testing. Also provided are the curve fits to the Freundlich/Langmuir hybrid equilibrium model as given in Eq. (4.5)(Hamm et al. 2002):

$$Q = \frac{\alpha_I \times [Cs]}{(\beta + [Cs])} \tag{4.5}$$

where:

[Cs]	=	equilibrium Cs concentration, mmoles/mL or M
Q	=	equilibrium Cs loading on the CST, mmole Cs per g CST
α_i	=	isotherm parameter constant (mmoles/g), equivalent to total capacity in the matrix
β	=	isotherm parameter constant (mmoles/mL or M), selectivity coefficient, dependent on matrix and temperature; the larger the value, the less selective the CST is for Cs (Hamm et al. 2002)

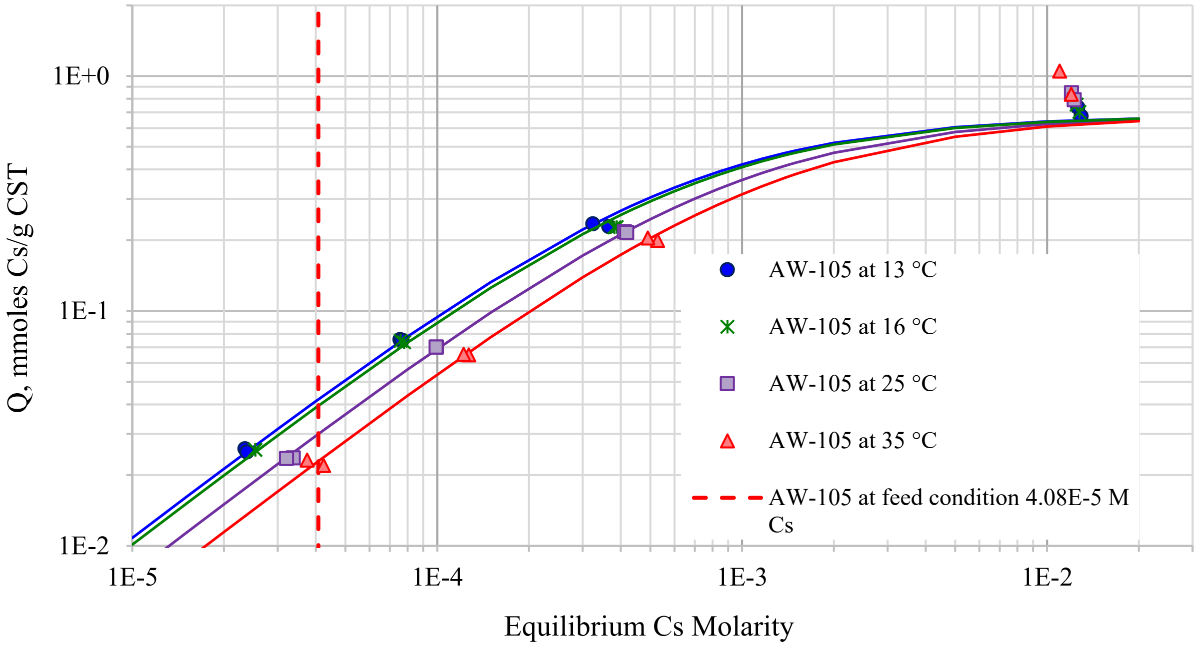

Figure 4.8. Q vs. Cs Equilibrium Concentration, AW-105 Tank Waste with Freundlich/Langmuir Hybrid Equilibrium Fits, Four Temperatures. The dashed red line represents the Cs concentration (4.08E-5 M) in AW-105 feed.

A plot of Q (mmoles Cs/g CST) vs. temperature (Figure 4.9) indicates that the loading decreases linearly as temperature increases. This is consistent with all other data collected for previous tank waste matrices (Westesen et al. 2024).

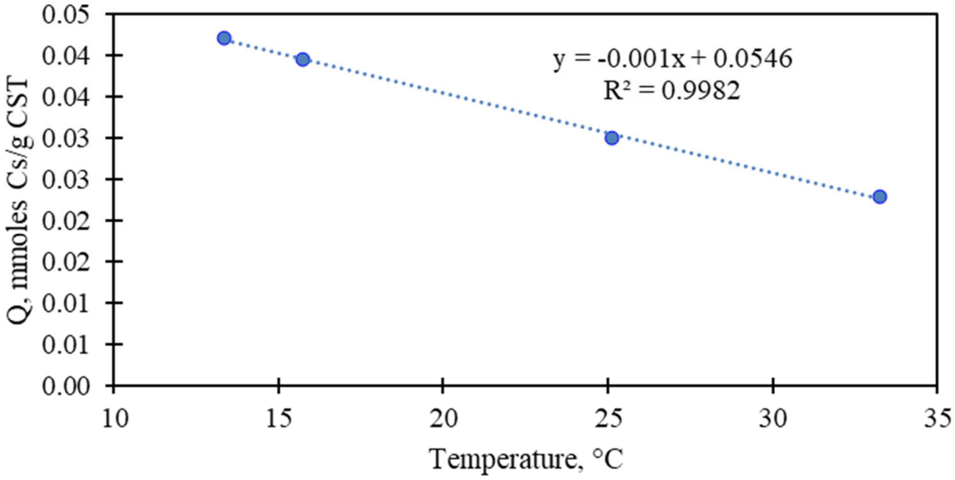

Figure 4.9. Q Dependence on Temperature for AW-105 Tank Waste

Batch contact testing with pre-IX AW-105 was conducted at ambient hot cell temperature to determine if removal of ions from column testing was impacting the batch contact results when column effluent was used. Figure 4.10 presents the isotherm that data alongside the 25 °C contact results from the post-IX AW-105 batch contacts. As expected, the pre-IX isotherm data falls below that of the post-IX data by nominally 20% and is indicative of the slightly lower Cs capacity experienced before any competitor ions are removed. K_d values for the two tests were 583 mL/g for pre-IX AW-105 and 734 mL/g for post-IX AW-105 at 25 °C.

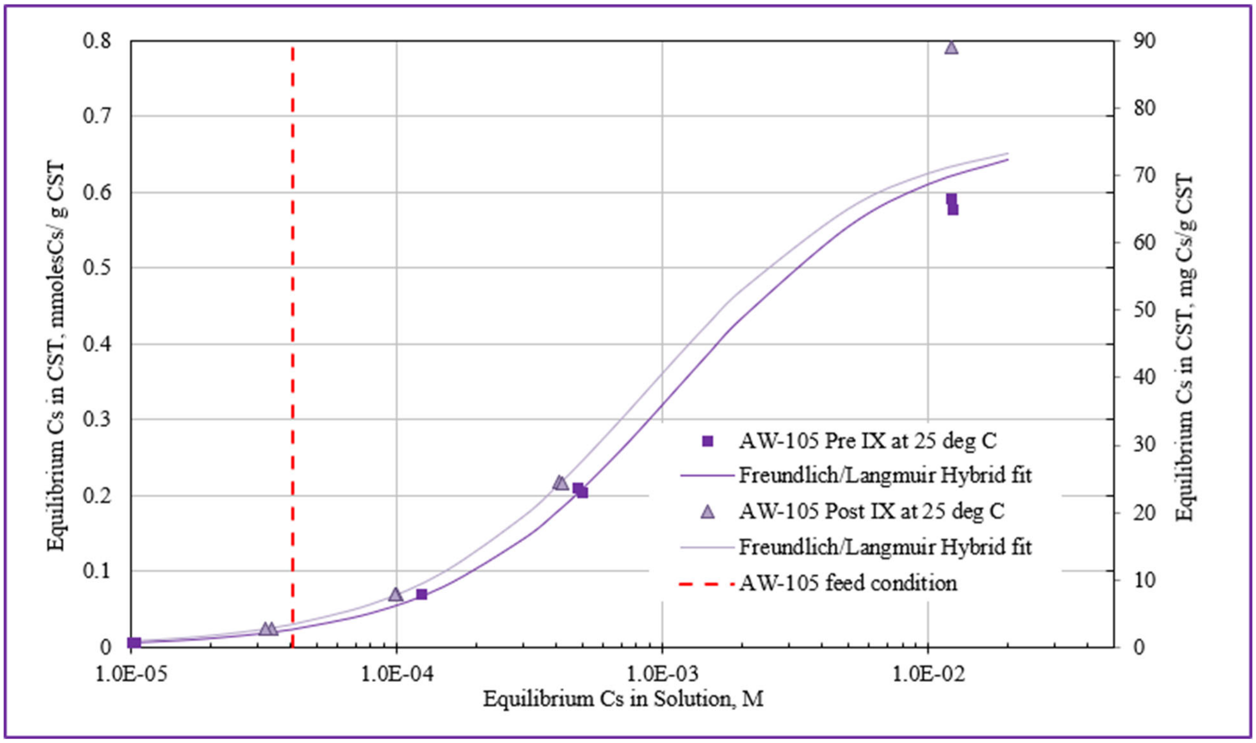

Figure 4.10. Equilibrium Isotherms for Pre- and Post-IX AW-105 with CST

4.2.2 Tank Waste Comparisons

Due to the increased K concentration in the AW-105 tank waste, a direct comparison of performance was not conducted with AP-107, AP-105, or AP-101 tank wastes. However, variable K batch contacts conducted on AN-107 (Westesen et al. 2024) assessed Cs removal of the waste at K concentrations between 0.05 and 1.0 M. Figure 4.11 compares that data with the data for AW-105. Data points displayed on the graph include the AW-105 batch contact sample at 25 °C as well as the column performance 50% breakthrough point. A temperature adjustment was made to the AW-105 column data point using the relationship determined from Figure 4.9 in order to directly compare the 16 °C data point to the AN-107 batch contacts that were conducted at 25 °C.

Excellent agreement is seen between the temperature-adjusted column and the 25 °C batch contact capacities, along with good alignment with the previous behavior determined for AN-107. At a K concentration of 0.58 M, the K_d for AW-105 is 730 mL/g and agrees within 2% of K_d values determined for AN-107 between 0.5 and 0.8 M K (760 and 759 mL/g, respectively). This shows that a portion of the performance deviation between AW-105 and the previously tested AP-107 is in direct relation to the differing K concentrations.

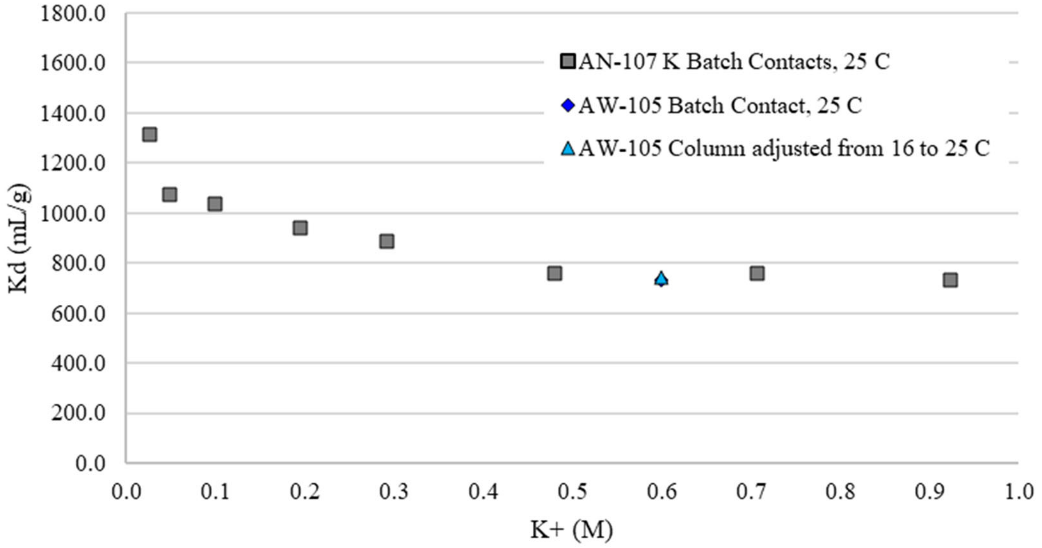

Figure 4.11. K_d Values vs. K Concentration for AW-105 and AN-107 Tank Waste

5.0 Conclusions

Cesium IX column testing was conducted with CST lot 2002009604 sieved to <30 mesh to assess Cs IX performance with AW-105 tank waste at 16 °C. Column testing was conducted at a small scale in hot cells at the PNNL Radiochemical Processing Laboratory to accommodate the high radiological dose rate of the Hanford tank waste matrix. The results are summarized below.

5.1 Column Testing

AW-105 tank waste was processed through two columns sequentially positioned in a lead-lag format; after processing 675 BVs, a polish column was placed in line. Each column was filled with 6.0 mL of CST ion exchanger. A total of 9.2 L of AW-105 tank waste, consisting of 5.5 M Na and 78 µCi/mL ^{137}Cs, was processed through the Cs IX system at 1.95 BV/h and 16 °C. Effluent samples were collected periodically from each column during the load process and measured for ^{137}Cs to establish the Cs load curves. The flowrate was increased to 3.0 BV/h to process a minimum of 12.0 BVs each of 0.1 M NaOH FD solution and water rinse. The following conclusions were drawn from the results of this work:

1. Testing showed that at 16 °C, 1041 BVs of AW-105 tank waste, processed at 1.95 BV/h, was calculated to be treated before reaching 50% Cs breakthrough on the lead column. The WAC limit was reached on the lag column when 772 BVs of AW-105 feed was processed. A polish column was installed and reached 0.3% breakthrough after processing ~830 BVs of feed.
2. The WTP LAW Facility WAC limit for the AW-105 lag column was reached only 20 BVs earlier than the respective lag column breakthrough with AP-107 at 16 °C (Westesen et al. 2021). Initial predictions expected a significantly earlier breakthrough due to the increased K concentration in AW-105; however, an additional assessment of the feed matrix found a significantly lower NO_3 concentration nearly offsetting the decreased performance due to K.
3. The total Cs loading onto the lead column (5.88 mg Cs/g CST) was notably lower than that seen in previous testing with AP-105, AP-101, and AP-107 (7.38, 7.31, and 7.08 mg Cs/g CST, respectively) at the same processing flowrate and temperature. This was likely caused by decreased Cs loading capacity due to the notably higher K concentration.
4. Analyte fractionation onto the CST was determined on the AW-105 feed and effluent composite samples. All major metal and anion components partitioned exclusively to the effluent. There was nominally 50% removal of Pu onto CST and over 98% removal of Sr.
5. Samples of the Cs-decontaminated tank waste were assessed for temperature precipitation down to 11 °C and found partial precipitation of B and Si.

5.2 Batch Contact Testing

Cs isotherms were developed for AW-105 tank waste at 13, 16, 25, and 35 °C with Cs concentrations of 20, 60, 200, and 2000 µg/mL Cs. Batch contacts were conducted in duplicate with 0.075 g dry CST (lot 2002009604) per 15 mL of solution and agitated in a temperature-controlled box for ~120 hours. The isotherm data were fit to the Freundlich/Langmuir hybrid equilibrium model and the linear Freundlich model to calculate K_d and Q values at an AW-105 feed condition of 4.08E-5 M (5.46 µg/mL) Cs. The following conclusions were made from this testing:

1. The Freundlich/Langmuir hybrid model accurately predicts the loading for all Cs concentrations chosen to bound the AW-105 feed condition. To further explore fidelity of the fit, the linear Freundlich isotherm was also determined to predict loading with $R^2 > 0.99$ for the four Cs concentrations at all temperatures.
2. The Cs loading at the AW-105 feed condition as calculated from batch contact testing at 16 °C was 0.0394 mmoles Cs/g CST, which was in good agreement with the predicted loading of 0.0424 mmoles Cs/g CST as calculated from the 50% breakthrough of the AW-105 lead column.
3. Batch contact testing with pre-IX AW-105 showed decreased loading compared to post-IX batch contacts at the same temperature. This is due to the competitor ions that are removed during column testing.
4. Overall Cs capacity of the AW-105 fell significantly below that of previously tested tank wastes and is attributed to the increased K concentration. This was confirmed by comparison to the AN-107 batch contact loading at 0.6 M K, which showed that the Cs capacity agreed within 2% of the AW-105 capacity at the same K concentration.

6.0 References

10 CFR 830, Subpart A. *Quality Assurance Requirements*. Code of Federal Regulations.

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Appendix A – Column Load Data

Table A.1 presents the raw data for AW-105 lead, lag, and polish column loading. These data include the processed bed volumes (BVs) and corresponding ^{137}Cs concentration in the collected sample, % C/C_0, and the Cs decontamination factor (DF).

Table A.1. Lead, Lag, and Polish Column Cs Breakthrough Results with AW-105

Lead Column				Lag Column				Polish Column			
BV	µCi ^{137}Cs/ mL	% C/C_0	DF	BV	µCi ^{137}Cs/ mL	% C/C_0	DF	BV	µCi ^{137}Cs/ mL	% C/C_0	DF
11	1.44E-2	1.85E-2	5.39E+3	34	4.64E-4	5.97E-4	1.68E+5	711.9	1.66E-4	2.13E-4	4.69E+5
34	5.29E-3	6.80E-3	1.47E+4	118	5.28E-4	6.79E-4	1.47E+5	761.0	2.60E-4	3.35E-4	2.99E+5
44	1.35E-3	1.73E-3	5.78E+4	161	2.57E-4	3.31E-4	3.03E+5	814.5	2.81E-4	3.62E-4	2.77E+5
68	1.29E-3	1.66E-3	6.02E+4	205	1.91E-4	2.45E-4	4.08E+5	899.0	9.91E-4	1.27E-3	7.85E+4
119	1.06E-2	1.37E-2	7.32E+3	300	2.53E-4	3.26E-4	3.07E+5	942.5	2.69E-3	3.46E-3	2.89E+4
206	9.73E-2	1.25E-1	7.99E+2	343	3.82E-4	4.91E-4	2.04E+5	995.4	4.06E-3	5.22E-3	1.92E+4
260	3.69E-1	4.75E-1	2.11E+2	480	4.46E-3	5.73E-3	1.74E+4	1038.8	6.57E-3	8.45E-3	1.18E+4
302	6.24E-1	8.03E-1	1.25E+2	535	1.18E-2	1.52E-2	6.57E+3	1081.4	9.33E-3	1.20E-2	8.33E+3
398	2.07E+0	2.66E+0	3.76E+1	623	3.27E-2	4.20E-2	2.38E+3	1125.1	1.95E-2	2.50E-2	3.99E+3
483	3.82E+0	4.91E+0	2.04E+1	677	7.41E-2	9.52E-2	1.05E+3	1181.0	2.21E-2	2.85E-2	3.51E+3
583	7.32E+0	9.41E+0	1.06E+1	716	9.75E-2	1.25E-1	7.98E+2	1225.6	3.34E-2	4.30E-2	2.33E+3
680	1.34E+1	1.73E+1	5.79E+0	766	1.74E-1	2.24E-1	4.46E+2	1269.2	6.21E-2	7.98E-2	1.25E+3
720	1.55E+1	2.00E+1	5.01E+0	819	2.80E-1	3.60E-1	2.77E+2	1324.9	9.92E-2	1.28E-1	7.84E+2
823	2.40E+1	3.09E+1	3.24E+0	864	3.88E-1	4.99E-1	2.01E+2	1381.8	1.22E-1	1.57E-1	6.39E+2
869	2.61E+1	2.00E+1	5.01E+0	905	4.61E-1	5.93E-1	1.68E+2	1420.1	1.64E-1	2.11E-1	4.73E+2
910	2.91E+1	3.74E+1	2.67E+0	948	6.49E-1	8.34E-1	1.20E+2	1463.8	2.10E-1	2.70E-1	3.71E+2
1007	3.71E+1	4.77E+1	2.10E+0	1002	1.05E+0	1.35E+0	7.41E+1				
1138	4.44E+1	5.71E+1	1.75E+0	1088	1.61E+0	2.07E+0	4.82E+1				
1283	5.33E+1	6.86E+1	1.46E+0	1132	2.06E+0	2.65E+0	3.77E+1				
1397	6.15E+1	7.91E+1	1.26E+0	1233	3.31E+0	4.25E+0	2.35E+1				
1479	6.40E+1	8.23E+1	1.21E+0	1277	4.16E+0	5.35E+0	1.87E+1				
1522	6.48E+1	8.33E+1	1.20E+0	1390	7.22E+0	9.29E+0	1.08E+1				
				1472	9.30E+0	1.20E+1	8.36E+0				
				1515	1.10E+1	1.41E+1	7.08E+0				

C_0 = 77.8 µCi ^{137}Cs/ mL (reference date January 2025)

Appendix B – Analytical Reports

This appendix includes analytical reports provided by Pacific Northwest National Laboratory's Analytical Support Operations (ASO) laboratory. In addition to the analyte results, these reports define the procedures used for chemical separations and analysis, as well as quality control sample results, observations during analysis, and overall estimated uncertainties. The analyses are grouped according to analytical request or task order number. Cross-references of sample IDs to test descriptions are provided in Table 3.6 of the main report.

Appendix B Table of Contents

AW-105 Ion Exchange Feed and Effluent Analysis Samples

ASO Analytical Service Request (ASR) 2256

331 Analytical request 2506006

Analytical Service Request (ASR)

(Information on this COVER PAGE is applicable to all samples submitted under this ASR)

Requestor --- Complete all fields on this COVER PAGE, unless specified as optional or ASR is a revision

Requestor:
Signature _______ Amy Westesen __________________
Print Name ________Amy Westesen__________________
Phone ____371-7908___________ MSIN ___________

Project Number: ________85442_______________
Work Package: _______NW2684______________

Matrix Type Information

- ◆ **Liquids:** ☒ Aqueous ☐ Organic ☐ Multi-phase
- ◆ **Solids:** ☐ Soil ☐ Sludge ☐ Sediment ☐ Glass ☐ Filter ☐ Metal ☐ Smear ☐ Organic ☐ Other
- ◆ **Other:** ☐ Solid/Liquid Mixture, Slurry ☐ Gas ☐ Biological Specimen

(If sample matrices vary, specify on Request Page)

QA/Special Requirements

- ◆ **QA Plan:**
  - ☒ASO-QAP-001 (Equivalent to HASQARD)
  - ☐ Additional QA Requirements, List Document Below:
  - Reference Doc Number:_________________________
- ◆ **Field COC Submitted?** ☒ No ☐ Yes
- ◆ **Lab COC Required?** ☒ No ☐ Yes
- ◆ **Sample/Container Inspection Documentation Required?** ☒ No ☐ Yes
- ◆ **Hold Time:** ☒ No ☐ ***Yes***

If *Yes*, Contact ASO Lead before submitting Samples
☐ Use SW 846 (PNL-ASO-071, identify analytes/methods where holding times apply)
☐ Other? Specify: ______________________

- ◆ **Special Storage Requirements:** ☒ None ☐ Refrigerate ☐ Other, Specify: _____________
- ◆ **Data Requires ASO Quality Engineer Review?** ☐ No ☒ Yes

Disposal Information

◆ **Disposition of Virgin Samples:**
Virgin samples are returned to requestor unless archiving provisions are made with receiving group!
If archiving, provide:
Archiving Reference Doc: __________________

◆ **Disposition of Treated Samples:**
☒ Dispose ☐ Return

Data Reporting Information

◆ **Is Work Associated with a Fee-Based Milestone?** ☒ No ☐ Yes
If yes, milestone due date:
____

◆ **Preliminary Results Requested, As Available?** ☐ No ☒ Yes

◆ **Data Reporting Level**
☒ ASO-QAP-001 (Equivalent to HASQARD).
☐ Minimum data report.
☐ Project Specific Requirements: Contact ASO Lead or List Reference Document:____________________

◆ **Requested Analytical Work Completion Date:**
____
(Note: Priority rate charge for < 10 business day turn-around time)

◆ **Negotiated Commitment Date:**
____
(*To be completed by ASO Lead*)

Waste Designation Information

◆ **ASO Sample Information Check List Attached?** ☐ No ☐ Yes
If no, Reference Doc Attached: _________________________
or, Previous ASR Number: ____________________________
or, Previous RPL Number: _________________________

Does the Waste Designation Documentation Indicate Presence of PCBs?
☐ **No** ☐ **Yes**

Send Report To: ____**AM Westesen**_______________ **MSIN** ___________________
_______________________________ **MSIN** ___________________
Additional or Special Instructions ____

Receiving and Login Information (*to be completed by ASO staff*)

Date Delivered: ______________
Delivered By (optional) __________________________
Time Delivered: __________________________
Group ID (optional) __________________________
CMC Waste Sample? **X** No ☐ Yes

Received By: _________________
ASR Number: _2256 Rev.: _00___
RPL Numbers: (25-0752) to _(25-0762)___
(first and last)

ASO Work Accepted By: ____________________ **Signature/Date:** ___________________________________

Provide Analytes of Interest and Required Detection limits - ☐ Below ☐ Attached

ASO Staff Use Only RPL Number	Customer Sample ID	Sample Description (& Matrix, if it varies)	Analysis Requested	ASO Staff Use Only Test	Library
25-0752	TI180-COMP-FEED	AW-105 tank waste	1) GEA- All samples (Cs-137, Co-60, Am-241 and Eu-154 and any other observed gamma emitting isotopes) 2) OH 3) IC Anions – F, Cl, NO_3, NO_3, PO_4, C_2O_4, and SO_4. 4) TIC/TOC- Hot persulfate 5) Tc-99 6) Sr-90 7) Np-AEA, Np-237 8) Pu-AEA, Pu-238, Pu-239/240 9) Am-AEA, Am-241 10) Acid Digestion-128 Prep Lab a) ICP/OES- Al, As, Ba, Ca, Cd, Cr, Fe, K, Na, Ni, P, Pb, S, Sr, Ti, U, Zn, Zr b) ICP-MS – Ba, Nb, Pb, Sr, U-238		
25-0753	TI180-COMP-EFF				
25-0754	TI180-A-1-A	AW-105 tank waste	1) Sr-90 2) Np-AEA, Np-237 3) Pu-AEA, Pu-238, Pu-239/240 4) Am-AEA, Am-241 5) Acid Digestion-128 Prep Lab a) ICP/OES- Al, As, Ba, Ca, Cd, Cr, Fe, K, Na, Ni, P, Pb, S, Sr, Ti, U, Zn, Zr b) ICP-MS – Ba, Nb, Pb, Sr, U-238		
25-0755	TI180-A-3-A				
25-0756	TI180-A-6-A				
25-0757	TI180-A-9-A				
25-0758	TI180-A-12-A				
25-0759	TI180-A-15-A				
25-0760	TI180-A-18-A				
25-0761	TI180-A-20-A				
25-0762	TI180-A-22-A				

ASR # _____2256__Rev.: ___00___

Page _____1_____ of _____1_______

Complete all fields on the ASR unless they are labeled as "optional" or for "Lab Staff use only", or the ASR is a revision representing changes to an ASR (original or revision). For an ASR revision, only include information for fields that have changed from the previous version of the ASR. Following is a list of fields and a brief description of the required information. If you have any questions, please call your ASO contact or the ASO Administrator at (509) 375-5457.

COVER PAGE

Requestor Name/Signature: This should be completed by the individual authorized to request the analytical services. With concurrence of the ASO Lead, the signature provided is taken as authorization to perform work as documented on the ASR. Requestor and/or ASO staff member signature is required for a customer authorized ASR revision.

Project Number/Charge Code: Provide the Charge Code to be used for performing the work requested by the ASR. If multiple Charge Codes are to be used, enter "Multiple" and provide appropriate Charge Codes and percentage distribution on the REQUEST PAGE. Provide PNNL/Battelle Project Number.

Matrix Type Information: If one matrix is being submitted, check appropriate matrix. If sample matrices vary among the samples being submitted, specify the matrix for each sample under "Customer Sample Description" on the REQUEST PAGE.

Disposal Information: For treated samples (i.e., subjected to processing for analysis), indicate whether the Lab Staff are to dispose according to governing Waste Management policy or return them to the requestor. Virgin samples (i.e., as received from the requestor) are returned to the requestor unless archiving provisions are made with the ASO. ASR information provided by the requestor shall define the archiving requirements and identify the funding source for archiving activities.

QA/Special Requirements:

QA Plan: Specify the Quality Assurance Plan applicable to the work. The ASO-QAP-001 (Equivalent to HASQARD) is the QA plan routinely used by ASO. The HASQARD is typically requested to support regulatory-driven requirements. Additional QA Requirements may be specified by including the referenced documents. If there are QA requirements that do not fall in either of these two categories, contact the ASO Lead for further direction.

Field COC? Lab COC Required?: Specify if the sample is submitted under a Field Chain of Custody (COC) and whether detailed Lab COC documentation must be maintained while sample is in the custody of the ASO. If Lab COC is required, all transfers of virgin and processed samples between buildings and outside the ASO will be documented. Discuss your requirements with the ASO Lead.

Hold Time: If applicable, specify which regulatory protocol hold times apply (e.g., RCRA or CERCLA) and provide the "Date Sampled" and the "Time Sampled"; otherwise, specify "None". For samples with holding time requirements, contact the ASO Lead to ensure adequate arrangements are in place for sample receipt, prior to submitting samples for analyses. (Note: Unless notified otherwise, ASO will use the date and time sampled as the basis for determining holding time.)

Special Storage Requirements: Indicate whether sample requires refrigeration or specify other special storage requirements.

ASO Quality Engineer Review Required? Indicate whether a data quality review is required. A data quality review is a review conducted by the ASO Quality Engineer to determine whether the resulting analytical data package(s) met the data quality objectives of the project. The quality review is in addition to the standard "Technical Review" to verify technical accuracy.

Data Reporting Information:

Fee Based Milestone Work: If the analytical work is associated with a fee based milestone, mark accordingly and include the date the analytical work is needed to support the milestone.

Preliminary Results Requested, as Available? If preliminary results are required (i.e., results reported prior to final report being issued) mark accordingly. Preliminary results are results that have been technically reviewed, but have not been thoroughly evaluated for meeting project QA and QC sample requirements. Issuing preliminary results typically adds cost.

Data Reporting Level: Specify the data reporting level that is required to meet project requirements. ASO-QAP-001 is designed to provide data reporting that meets the needs of most regulatory programs. The minimum data report provides results with minimal supporting data. (i.e., no narrative, QC data as applicable, independent technical review). Project-specific reporting requirements can be specified to include both hardcopy and electronic formats.

Requested Analytical Work Completion Date: Specify the date that you need the report delivered in order to meet programmatic requirements. If date required is within 10 business days of the request, premium charges may be assessed. (**Note:** This date may be subject to change based on negotiated agreement between the project and the ASO Lead)

Waste Designation Information: Requester may attach an ASO Sample Information Check List (SICL) to each ASR that details the hazards associated with the samples and provides waste designation information. In lieu of an ASO SICL, the requestor may reference previous SICLs by either ASR or RPL Numbers, or provide other process knowledge documentation that provides the required SICL information (i.e., Reference Doc#). The requestor is to indicate whether PCBs are present or not.

Additional or Special Instructions: If there are additional instructions not described on this ASR, a Reference Document may be specified which provides the instructions.

Send Report to: Specify the name and mail stop of the individual(s) receiving the report.

REQUEST PAGE

RPL Number, Test Name, Library: Leave these fields blank.

Customer Sample ID: Provide a unique identification number (or name) for each sample submitted on the ASR.

Sample Description: Provide a brief sample description (e.g., sample type, preservation). Include matrix type from COVER PAGE if samples are of various matrices.

Analysis Requested: List analytical tests to be performed on the sample. For analytical tests that that measure multiple analytes (e.g., ICP, GEA, IC) provide a list of "analytes of interest". Besides the analyte list, provide required detection limits. The analytical tests, analyte list, and required detection limits may be provided on an attachment

Pacific Northwest National Laboratory
Richland, WA
Nuclear Chemistry and Engineering

Filename: ASR 2256 Westesen GEA report
2/27/2025

Client: A Westesen
ASR: 2256

Project: 85442
Charge code: NW2684

Analyst: Truc Trang-Le Digitally signed by Truc Trang-Le Date: 2025.03.03 11:08:25 -08'00'

Concur: Lawrence R Greenwood Digitally signed by Lawrence R Greenwood Date: 2025.03.03 11:22:45 -08'00'

Procedure: Activity #8693- Gamma Energy Analysis (GEA) and Low-Energy Photon Spectrometry (LEPS)
M & TE: Detectors T
Count date: February 26-27, 2025

Measured Activity, µCi/sample ± 1s

RPL ID:	25-0752		25-0753	
Sample ID:	TI180-COMP-FEED		TI180-COMP-EFF*	
Reference Date	2/26/2025		2/26/2025	
Isotope	µCi/sample	+/-	µCi/sample	+/-
Co-60	**7.74E-04**	**± 2.0%**	**2.47E-03**	**± 2.4%**
Cs-137	**3.80E+02**	**± 2.0%**	**3.57E-01**	**± 2.0%**
Eu-152	<3.0E-03		<2.2E-04	
Eu-154	<6.1E-03		**3.74E-04**	**± 17.7%**
Eu-155	<8.7E-02		<9.1E-04	
Am241	<2.9E-01		<3.4E-03	

* The sample geometries did not exactly match our calibrated geometries such that the absolute uncertainties are a bit higher than listed on the report.

Pacific Northwest National Laboratory
Analytical Support Operations
Chemical Measurements Center

ASR: 2256
Client: A. Westesen
Report Date: July 2, 2025
Analysis Date: June 30, 2025

Hydroxide Analysis of Tank Waste Samples

Sample preparation and analysis

Hydroxide analysis was performed on aliquots from one aqueous sample: 25-0753. Analysis was not done on sample 25-0752 due to lack of sample. The analysis was conducted using a Metrohm 905 Titrando autotitrator to determine the hydroxide content. Procedures followed for analysis include the following lab assist activities:

- #4448 “Metrohm Autotitrator”
- #7897 "Measurement of pH in Aqueous Solutions"
- #7898, "Determination of Hydroxyl and Alkalinity of Aqueous Solutions, Leachates, and Supernates."

Titrations were performed using standardized HCl solution (0.1000 ± 0.0002 M, Fisher Lot: M11L52, expiration date: 07/16/2026). Matrix spike and blank spike samples used standardized NaOH solution (0.1000 ± 0.0002 M, Fisher Lot: Z146504, expiration date: 06/23/2026).

For sample preparation:

1. Aliquoting: each sample (0.4 mL) was measured into a digestion tube, and the tubes were weighed before and after aliquoting.
2. Dilution: Samples were diluted with DI water (approximately 20mL) to immerse the pH probe fully
3. Titration: A burette was used to add the standardized 0.1 M HCl solution incrementally to perform the titration.

The samples reported are as follows:

- 25-0753
  - 0.4 mL (0. 5107 g) aliquot of TI180-COMP-EFF (25-0753)
  - A duplicate sample 0.4 mL (0.5061 g) aliquot of TI180-COMP-EFF (25-0753 Dup)
  - a matrix spike composed of 0.4 mL (0.5120 g) aliquot of TI180-COMP-EFF spiked with 2 mL (2.01g) 0.1 M NaOH (25-0753 MS)

Hydroxide Analysis

OH concentration was determined via the first inflection point by subtracting the carbonate contribution as follows:

- The titration curve was analyzed to determine equivalence points based on the maximum absolute slope along the curve

- First inflection point: corresponds to the neutralization of NaOH and the neutralization of Na_2CO_3 to $NaHCO_3$. This inflection point is reached when all the NaOH had been neutralized and when all the Na_2CO_3 has been converted to $NaHCO_3$.

- Second inflection point: corresponds to the complete neutralization of the $NaHCO_3$ to H_2CO_3.

- Carbonate concentration: calculated from the moles of titrant used between the first and second inflection points.

- Hydroxide concentration: calculated by subtracting the Na_2CO_3 contribution from the first inflection point. An example calculation is shown below.

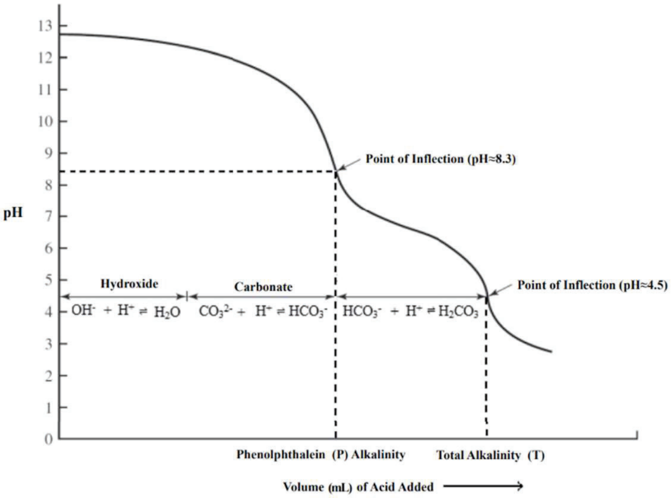

Figure 1: Typical acid titration curve for hydroxide carbonate system

Example Calculation for OH Concentration

1. Determine the moles of HCl added to reach the first inflection point (pH≈8.3). The moles of HCl added to reach this inflection point will be equal to the moles of OH and the moles of Na_2CO_3, combined. Let's call this value x.

$$x = \text{ moles of acid at } \mathrm{V}_1 = \text{moles of OH} + \text{moles of } \mathrm{Na_2CO_3}$$

where V_1 is the total volume of acid required to reach the first inflection point

2. Determine the moles of HCl added to reach the second inflection point (pH≈4.5). The moles of HCl needed to reach this inflection point will be equal to the moles of bicarbonate only. Let's call this value y.

$$y = \text{moles of } \mathrm{NaHCO_3} \text{ at } V_2 = V_2 - V_1$$

where V_2 is the volume of HCl required to reach the second inflection point from the first inflection point. This value will also be equal to the moles of Na_2CO_3

$$y = \text{moles of NaHCO}_2 = \text{moles of Na}_2\text{CO}_3$$

3. The moles of OH can then be determined by subtracting the moles of $NaHCO_3$ found in step 2 from the moles of OH and Na_2CO_3 found in step 1.

$$\text{moles of OH} = y - x$$

Sample Results

The HCl volume and corresponding pH were used to determine the inflection point for each sample indicating the equivalence point for the hydroxide neutralization.

ASO Sample ID	Client Sample ID	First Inflection Point (pH)	Hydroxide Concentration (mol/kg)	Average Hydroxide Concentration (mol/kg)	Relative Percent Difference	Acceptance Criteria for Relative Percent Difference	Second Inflection Point (pH)	Carbonate Concentratio (mol/kg)
25-0753	TI180-COMP-EFF	7.9390	1.32	1.325	1%	≤ 20%	4.6439	0.70
25-0753 Dup	TI180-COMP-EFF	7.8673	1.33				4.7666	0.68

Quality Control Results

Quality control samples include:

- Matrix spike: sample 25-0753 with 2.01 mL of 0.1 M NaOH spike.
- Blank spike: DI H_2O with 2.01 mL of 0.1 M NaOH spike.
- Process blank: DI H_2O.

Theoretical hydroxide concentrations were compared to measured concentrations, with both the matrix spike and blank spike recovery falling within the acceptable yield criteria. Samples were prepared on the day of analysis to minimize carbonate buildup, as insufficient time was allowed for significant formation.

ASO Sample ID	Yield (%)	Acceptance criteria for Yield (%)
25-0753 Matrix Spike	93	75-125%
25-0721 Blank Spike	100	75-125%
Process Blank	N/A	N/A

Instrument Calibration Control

The pH meter was calibrated using 3 buffers, pH 4, 7 and 10 and the calibration verified using an independent pH 7 buffer.

Prepared by:

James Waller
Digitally signed by James Waller
Date: 2025.07.10 11:59:50 -07'00'

Reviewed by:

Catalin Harabagiu
Digitally signed by Catalin Harabagiu
Date: 2025.07.15 15:56:44 -07'00'

Pacific Northwest National Laboratory
Richland, WA
Nuclear Chemistry and Engineering

Filename: ASR 2256 Westesen Tc report
6/10/2025

Client: A Westesen
ASR: 2256

Project: 85442
Charge code: NW2684

Analyst: Lawrence R Greenwood Digitally signed by Lawrence R Greenwood Date: 2025.06.10 08:41:58 -07'00'

Concur: Truc Trang-Le Digitally signed by Truc Trang-Le Date: 2025.06.10 08:43:29 -07'00'

Procedure: Lab Assist activity 10133, Radiochemical Separations using Column Chromatography, Tc TEVA Separation Method

M & TE: Perkin Elmer TriCarb model 3100 R
Count date: 2-Jun-25

Sample	Lab ID	**Tc-99 µCi per g**	
TI180-COMP-FEED	25-0752	**2.48E-02**	**± 3%**
	25-0752DUP	**2.51E-02**	**± 3%**
TI180-COMP-EFF	25-0753	**2.36E-02**	**± 3%**
	25-0753DUP	**2.42E-02**	**± 3%**
	Reagent Spike	104%	
	Matrix Spike	107%	
	Matrix Spike	111%	
	Lab prep blank	-2.34E-07	± 137%

Pacific Northwest National Laboratory
Richland, WA
Nuclear Chemistry and Engineering

Filename: ASR 2256 Westesen Sr report
6/30/2025

Client: A Westesen
ASR: 2256

Project: 85442
Charge code: NW2684

Analyst: Truc Trang-Le Digitally signed by Truc Trang-Le Date: 2025.06.30 13:34:10 -07'00'

Concur: Lawrence R Greenwood Digitally signed by Lawrence R Greenwood Date: 2025.06.30 13:27:13 -07'00'

Procedure: Lab Assist activity 10133, Radiochemical Separations using Column Chromatography, Tc TEVA Separation Method

M & TE: Perkin Elmer TriCarb model 3100 R
Count date: June 17-23 , 2025

Sample	Lab ID	**Sr-90 µCi per g**	
TI180-COMP-FEED	25-0752	**2.30E-02**	**± 2%**
TI180-COMP-EFF	25-0753	**2.91E-04**	**± 2%**
	25-0753DUP	**2.95E-04**	**± 2%**
TI180-A-1-A	25-0754	**6.78E-03**	**± 2%**
TI180-A-3-A	25-0755	**3.81E-03**	**± 2%**
TI180-A-6-A	25-0756	**3.65E-03**	**± 2%**
TI180-A-9-A	25-0757	**4.65E-03**	**± 2%**
TI180-A-12-A	25-0758	**1.49E-03**	**± 2%**
	25-0758 DUP	**1.43E-03**	**± 2%**
TI180-A-15-A	25-0759	**1.08E-03**	**± 2%**
TI180-A-18-A	25-0760	**1.48E-03**	**± 2%**
TI180-A-20-A	25-0761	**2.20E-03**	**± 2%**
TI180-A-22-A	36-0762	**1.19E-03**	**± 2%**
	Reagent Spike	121%	
	Matrix Spike 0753	119%	
	Lab prep blank 0753	4.03E-06	± 8%
	Lab prep blank 0758	3.33E-06	± 10%

Pacific Northwest National Laboratory
Richland, WA
Nuclear Chemistry and Engineering

Filename: ASR 2256 Westesen AEA report
6/30/2025

Client: A Westesen
ASR: 2256

Project: 85442
Charge code: NW2684

Analyst: Lawrence R Greenwood
Digitally signed by Lawrence R Greenwood
Date: 2025.07.02 08:18:37 -07'00'

Concur: Catalin Harabagiu
Digitally signed by Catalin Harabagiu
Date: 2025.07.02 15:27:50 -07'00'

Procedure: Activity - 7963, "Co-precipitation Mounting of Actinides for Alpha Spectroscopy"
M & TE: AEA Detectors
Count date: June 9-30, 2025

Nuclide:		Pu-238		Pu-239+240		Np-237		Am-241	
RPL ID	Sample	µCi/g	+/-	µCi/g	+/-	µCi/g	+/-	µCi/g	+/-
25-0752	**TI180-COMP-FEED**	1.54E-5	± 7%	7.15E-5	± 5%	2.15E-6	± 5%	5.26E-5	± 2%
25-0753	**TI180-COMP-EFF**	8.42E-6	± 9%	3.80E-5	± 5%	1.95E-6	± 6%	5.40E-5	± 2%
25-0753 dup	**TI180-COMP-EFF**	3.52E-6	± 11%	4.06E-5	± 4%	2.68E-6	± 4%	5.37E-5	± 2%
25-0754	**TI180-A-1-A**	8.97E-6	± 5%	3.20E-5	± 3%	1.10E-6	± 18%	9.81E-5	± 2%
25-0755	**TI180-A-3-A**	3.87E-6	± 9%	3.47E-5	± 4%	1.05E-6	± 29%	1.30E-4	± 2%
25-0756	**TI180-A-6-A**	1.44E-5	± 5%	1.01E-4	± 3%	2.70E-6	± 4%	4.88E-5	± 2%
25-0757	**TI180-A-9-A**	7.51E-6	± 6%	5.42E-5	± 3%	3.15E-6	± 3%	4.18E-5	± 2%
25-0758	**TI180-A-12-A**	1.16E-5	± 3%	5.82E-5	± 2%	1.64E-6	± 8%	3.52E-5	± 2%
25-0758 dup	**TI180-A-12-A**	1.21E-5	± 4%	5.96E-5	± 2%	2.22E-6	± 5%	3.75E-5	± 2%
25-0759	**TI180-A-15-A**	1.24E-5	± 3%	6.14E-5	± 2%	1.94E-6	± 6%	3.28E-5	± 2%
25-0760	**TI180-A-18-A**	1.23E-5	± 3%	6.27E-5	± 2%	2.67E-6	± 4%	2.76E-5	± 2%
25-0761	**TI180-A-20-A**	1.33E-5	± 4%	6.75E-5	± 2%	2.48E-6	± 4%	2.99E-5	± 3%
25-0762	**TI180-A-22-A**	1.27E-5	± 4%	6.37E-5	± 2%	2.86E-6	± 4%	3.02E-5	± 2%
25-0753 PB		5.59E-9	± 100%	9.39E-8	± 25%	9.00E-8	± 77%	1.00E-7	± 11%
25-0758 PB		< 2.3E-8		7.20E-8	± 20%	6.01E-8	± 140%	7.98E-8	± 18%
Reagent Spike				103%		78%		95%	
Matrix Spike				85%		92%		90%	

Battelle PNNL/RPL/Inorganic Analysis … ICP-OES Analysis Report
PO Box 999, Richland, Washington 99352

Project / WP#: 85442 / NW2684
ASR#: 2256
Client: A. Westesen
Total Samples: 11 (liquid)

ASO Sample ID	Client Sample ID	Client Sample Description
25-0752	TI180-COMP-FEED	AW-105 tank waste
25-0753	TI180-COMP-EFF	AW-105 tank waste
25-0754	TI180-A-1-A	AW-105 tank waste
25-0755	TI180-A-3-A	AW-105 tank waste
25-0756	TI180-A-6-A	AW-105 tank waste
25-0757	TI180-A-9-A	AW-105 tank waste
25-0758	TI180-A-12-A	AW-105 tank waste
25-0759	TI180-A-15-A	AW-105 tank waste
25-0760	TI180-A-18-A	AW-105 tank waste
25-0761	TI180-A-20-A	AW-105 tank waste
25-0762	TI180-A-22-A	AW-105 tank waste

Sample Preparation: Simple dilution of samples received from Radiochemistry in 5% v/v HNO3 performed by C. Perez.

Procedure: RPG-CMC-211, Rev. 4, "Determination of Elemental Composition by Inductively Coupled Argon Plasma Optical Emission Spectrometry (ICP-OES)."

Lab Assist Activity: ICP-OES Operations #4555 Version 1

Analyst(s):	C. Perez	**Analysis Date:**	5/19/2025	**ICP File:**	C1000

See Chemical Measurement Center 98620 file: ICP-325-405-3
(Calibration and Maintenance Records)

M&TE:		
	☒ PerkinElmer 5300DV ICP-OES	SN: 077N5122002
	☐ Sartorius ME414S Balance	SN: 21308482
	☒ Mettler AT400 Balance	SN: 1113162654
	☐ Sartorius R200D Balance	SN: 39080042
	☐ Mettler AT201 Balance	SN: 192720-92
	☒ Ohaus Pioneer PA224C	SN: B725287790
	☐ SAL Cell 2 Balance	SN: 8033311209

Christian Perez
Digitally signed by Christian Perez
Date: 2025.06.17 06:48:01 -07'00'

Report Preparer — Date

James Waller
Digitally signed by James Waller
Date: 2025.06.16 14:31:00 -07'00'

Review and Concurrence — Date

Battelle PNNL/RPL/Inorganic Analysis … ICP-OES Analysis Report

Eleven aqueous samples were submitted under Analytical Service Request (ASR) 2256 and was analyzed by ICP-OES. The sample had an acid digestion performed by the Radiochemistry team prior to analysis.

All sample results are reported on a mass per unit mass basis (µg/g) for each detected analyte. The data have been adjusted for instrument dilutions.

Analytes of interest (AOI) were specified in the ASR and are listed in the upper section of the attached ICP-OES Data Report. The quality control (QC) results for the AOI have been evaluated and are presented below. Analytes other than the AOI are reported in the bottom section of the report but have not been fully evaluated for QC performance.

Calibration of the ICP-OES was done following the manufacturer’s recommended calibration procedure using multi-analyte custom standard solutions traceable to the National Institute of Standards and Technology (NIST). Midrange calibration verification standards (MCVA and MCVB) were used to verify acceptance of the two-point calibration curves obtained for each analyte and for continuing calibration verification.

Limited Data: Ag (Silver), Bi (Bismuth), Ce (Cerium), S (Sulfur), Sb (Antimony), and Tl (Thallium) failed multiple ICV/CCV checks, and any data information is for information only and bias low.

The controlling documents were procedures RPG-CMC-211, Rev 4, *Determination of Elemental Composition by Inductively Coupled Argon Plasma Optical Emission Spectrometry (ICP-OES)*, and ASO-QAP-001, Rev. 11, *Analytical Support Operations (ASO) Quality Assurance Plan*. Instrument calibrations, QC checks and blanks (e.g., ICV/ICB, CCV/CCB, LLS, ICS), post-digestion spikes, duplicate, blank spike, and serial dilution were conducted during the analysis run.

Preparation Blank (PB):

A preparation blank was supplied with the samples by the radiochemistry team. All AOI except for Fe (Iron) were within the acceptance criteria of <EQL (estimated quantitation level), <50% regulatory decision level, or less than ≤5% of the concentration in the sample. Iron was slightly above the EQL, and very minimal Iron values were detected in the samples.

Blank Spike (BS)/Laboratory Control Sample (LCS):

A 50:50 mixture of the MCVA and MCVB solutions was analyzed as the blank spike. Recovery values are listed for all analytes included in the BS that were measured at or above the EQL. All AOI meeting this requirement were within the acceptance criterion of 80% to 120%. For the blank spike samples, Sulfur data fell between the Method Detection Limit (MDL) and the Estimated Quantitation Limit (EQL). This occurred due to the dilution of the sample, which was necessary to prevent any potential impact on the instrument's performance. The results were calculated manually and were deemed acceptable.

Battelle PNNL/RPL/Inorganic Analysis … ICP-OES Analysis Report

Duplicate/Replicate Relative Percent Difference (RPD):
A duplicate of sample 25-0752 Dup @25x was prepared and analyzed. All AOI detected were within the acceptance criterion of ≤20%. A duplicate of sample 25-0753 Dup @25x was prepared and analyzed. All AOI detected were within the acceptance criterion of ≤20%.

Triplicate Relative Standard Deviation (RSD):
No triplicate sample was analyzed.

Matrix-Spike (MS) Sample:
A matrix spike sample was created during sample preparation beforehand by the radiochemistry team.
For 25-0752 MS @25x, All AOI passed within the acceptance criterion. Chromium, Potassium, Sodium were an invalid test due the spikes being less than 25% of sample concentration.
For 25-0753 MS @25x, All AOI passed within the acceptance criterion except for Chromium, Potassium, Sodium were an invalid test due the spikes being less than 25% of sample concentration. Sulfur and Phosphorus data fell between the Method Detection Limit (MDL) and the Estimated Quantitation Limit (EQL). This occurred due to the dilution of the sample, which was necessary to prevent any potential impact on the instrument's performance. The results were calculated manually and were deemed acceptable.

Initial/Continuing Calibration Verification (ICV/CCV):
MCVA and MCVB solutions were analyzed immediately after calibration, after each group of not more than ten samples, and at the end of the analytical run. All AOI were within the acceptance criteria of 90% to 110% except for Sulfur (S), which failed low and therefore the data may be biased low. Non AOI data for Ag (Silver), Bi (Bismuth), Ce (Cerium) S (Sulfur), Sb (Antimony), and Tl (Thallium) failed multiple ICV/CCV checks, and any data information is for information only and bias low.

Initial/Continuing Calibration Blank (ICB/CCB):
The ICB/CCB solution (5% v/v HNO3) was analyzed immediately after the ICV solutions and after the CCV solutions (after each group of not more than ten samples and at the end of the analytical run). All AOI were within the acceptance criteria of <EQL.

Low-Level Standard (LLS):
The LLS solution was analyzed immediately after the first CCB solution. All AOI were within the acceptance criteria of 70% to 130%.

Interference Check Standard (ICS/SST):
The ICS solution was analyzed immediately after the first LLS solution and immediately prior to analyzing the final CCV solutions. Recovery values are listed for all analytes included in the SST that were measured at or above the EQL. All AOI were within the acceptance criteria of 80% to 120%.

Battelle PNNL/RPL/Inorganic Analysis … ICP-OES Analysis Report

Serial Dilution (SD):
A ten-fold serial dilution was conducted on sample 25-0752 @125x. The percent difference (%D) for all AOI was withing the acceptance criteria of ≤ 10%. A ten-fold serial dilution was conducted on sample 25-0753 @125x. The percent difference (%D) for all AOI was withing the acceptance criteria of ≤ 10%.

Post-Digestion Spike (PS-A+B) - Sample (A Component):
A post-digestion spike (A+B Components) were conducted on each sample. The sample spikes were MCVA and MCVB spikes. All AOI were within the acceptance criterion of 80% to 120%.

Other QC:
All other instrument-related QC tests for the AOI passed within their respective acceptance criteria.

Comments:

1) The "Final Results" have been corrected for all laboratory dilutions performed on the samples during processing and analysis, unless specifically noted.
2) Instrument detection limits (IDL) and estimated quantitation limits (EQL) shown are for acidified water and/or fusion flux matrices as applicable. Method detection limits (MDL) for individual samples can be estimated by multiplying the IDL by the "Process Factor" for that individual sample. The estimated quantitation limit (EQL) for each concentration value can be obtained by multiplying the EQL by the "Process Factor".
3) Routine precision and bias is typically ±15% or better for samples in dilute, acidified water (e.g. 5% v/v HNO_3 or less) at analyte concentrations > EQL up to the upper calibration level. This also presumes that the total dissolved solids concentration in the sample is less than 5000 µg/mL (0.5 per cent by weight). Note that bracketed values listed in the data report are within the MDL and the EQL, and have potential uncertainties greater than 15%. Concentration values < MDL are listed as "- -". Note, that calibration and QC standard samples are validated to a precision of ±10%.
4) Analytes included in the spike A component (for the AS/PS) are; Ag, Al, As, B, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Eu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, Sb, Se, Si, Sm, Sn, Sr, Ta, Ti, Tl, V, W, Y, Zn, and Zr. Analytes included in the spike B component are; Ce, Dy, Eu, La, Nd, Pd, Rh, Ru, S, Te, Th, and U.

Battelle PNNL/RPG/Inorganic Analysis ... ICPOES Data Report

		Run Date >	5/19/2025	5/19/2025	5/19/2025	5/19/2025	5/19/2025	5/19/2025	5/19/2025	5/19/2025	5/19/2025	5/19/2025	5/19/2025	5/19/2025	5/19/2025	5/19/2025	5/19/2025	5/19/2025
		Process Factor >	1.0	1.0	1.0	409.8	413.4	393.9	409.8	425.8	390.1	413.6	437.6	403.0	397.1	412.5	405.9	408.4
			405 Diluent	25-0752 PB @1x	25-0753 PB @1x	25-0752 @25x	25-0752 Dup @25x	25-0753 @25x	25-0753 Dup @25x	25-0754 @25x	25-0755 @25x	25-0756 @25x	25-0757 @25x	25-0758 @25x	25-0759 @25x	25-0760 @25x	25-0761 @25x	25-0762 @25x
Instr. Det. Limit (IDL)	Est. Quant. Limit (EQL)	Client ID >				TI180-COMP-FEED	TI180-COMP-FEED	TI180-COMP-EFF	TI180-COMP-EFF	TI180-A-1-A	TI180-A-3-A	TI180-A-6-A	TI180-A-9-A	TI180-A-12-A	TI180-A-15-A	TI180-A-18-A	TI180-A-20-A	TI180-A-22-A
(µg/g)	(µg/g)	(Analyte)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)
0.0091	0.091	Al	--	[0.030]	0.358	6,730	6,640	6,640	6,790	5,600	6,100	6,360	6,660	6,530	6,320	6,470	6,820	6,590
0.1768	1.768	As	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.0002	0.002	Ba	--	--	[0.0002]	[0.12]	[0.10]	--	--	[0.096]	--	--	--	--	--	--	--	--
0.0075	0.075	Ca	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.0079	0.079	Cd	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.0046	0.046	Cr	--	--	--	254	251	244	252	230	241	249	258	247	249	247	254	252
0.0025	0.025	Fe	[0.0039]	0.0295	[0.0074]	[2.6]	[2.9]	[3.9]	[2.5]	[7.2]	[2.3]	[4.1]	[5.0]	[3.7]	[4.1]	[3.2]	[3.7]	[3.3]
0.0352	0.352	K	--	[0.046]	--	17,900	17,600	17,000	17,400	15,000	17,000	17,200	17,800	17,800	17,300	17,500	18,100	17,500
0.0085	0.085	Na	--	--	--	102,000	100,000	97,800	100,000	90,700	97,400	99,200	102,000	102,000	98,500	99,700	103,000	99,500
0.0085	0.085	Ni	--	--	--	[4.5]	[4.2]	[5.7]	[7.4]	[4.4]	[5.0]	[5.2]	[5.7]	[6.5]	[3.5]	[5.3]	--	--
0.1778	1.778	P	--	--	--	[340]	[310]	[320]	[320]	[320]	[310]	[310]	[330]	[350]	[310]	[320]	[340]	[340]
0.0385	0.385	Pb	--	--	[0.041]	--	--	--	--	--	--	--	--	--	--	--	--	--
0.6450	6.450	S	--	--	--	[1,100]	[1,000]	[1,000]	[1,200]	[1,000]	[1,000]	[980]	[1,100]	[1,200]	[1,000]	[1,000]	[1,200]	[1,000]
0.0002	0.002	Sr	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.0007	0.007	Ti	--	[0.0037]	[0.0054]	--	[0.34]	[0.52]	[0.58]	[0.67]	[0.52]	[0.44]	[0.59]	[0.46]	[0.63]	[0.47]	[0.35]	[0.54]
0.0675	0.675	U	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.0087	0.087	Zn	--	[0.080]	[0.053]	[28]	[24]	[27]	[23]	[24]	[22]	[30]	[24]	[22]	[23]	[29]	[22]	[27]
0.0018	0.018	Zr	--	--	--	[1.4]	--	[3.6]	[3.4]	[1.4]	[2.7]	[2.1]	[1.4]	[1.3]	[1.5]	[1.4]	[2.5]	[1.1]
Other Analytes																		
0.0022	0.022	Ag	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.0193	0.193	B	[0.025]	--	[0.032]	[50]	[49]	[15]	[17]	91.0	95.4	81.5	[69]	80.5	79.9	[75]	[56]	[57]
0.0001	0.001	Be	--	--	--	1.43	1.43	1.32	1.36	[0.42]	1.18	1.37	1.43	1.36	1.38	1.38	1.41	1.41
0.0618	0.618	Bi	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.0163	0.163	Ce	--	[0.017]	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.0064	0.064	Co	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.0019	0.019	Cu	--	--	[0.0025]	[4.5]	[4.2]	[3.9]	[4.4]	[3.6]	[3.8]	[4.2]	[4.1]	[4.0]	[4.3]	[4.6]	[4.2]	[4.1]
0.0034	0.034	Dy	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.0006	0.006	Eu	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.0018	0.018	La	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.0015	0.015	Li	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.0025	0.025	Mg	--	[0.0045]	[0.020]	--	--	--	--	--	--	--	--	--	--	--	--	--
0.0007	0.007	Mn	--	--	--	[0.89]	[0.72]	[0.78]	[0.70]	[0.88]	[0.75]	[0.76]	[0.92]	[0.75]	[0.78]	[0.69]	[0.87]	[0.80]
0.0173	0.173	Mo	--	--	--	[10]	[14]	[14]	[19]	[15]	[18]	[13]	[15]	[20]	[20]	[13]	[20]	[19]
0.0126	0.126	Nd	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.0113	0.113	Pd	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.0389	0.389	Rh	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.0128	0.128	Ru	--	--	--	--	--	[7.6]	[5.4]	--	--	--	--	--	--	--	--	--
0.1139	1.139	Sb	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.4064	4.064	Se	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.0212	0.212	Si	--	2.15	2.81	[9.3]	[11]	--	--	[11]	[11]	[13]	[9.4]	[9.0]	--	[10]	[15]	[10]
0.1168	1.168	Sn	--	--	--	--	[51]	[64]	[52]	--	--	[68]	--	[55]	[50]	[57]	--	--
0.0320	0.320	Ta	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.0623	0.623	Te	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.0116	0.116	Th	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.1934	1.934	Tl	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.0029	0.029	V	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.0513	0.513	W	--	--	--	[35]	[24]	[34]	[38]	[29]	[39]	[37]	[39]	[30]	[37]	[27]	[28]	[39]
0.0006	0.006	Y	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

1) "--" indicates the value is < MDL. The method detection limit (MDL) = IDL times the "multiplier" near the top of each column. The estimated sample quantitation limit = EQL (in Column 2) times the "multiplier". Overall error for values ≥ EQL is estimated to be within ±15%.

2) Values in brackets [ ] are ≥ MDL but < EQL, with errors likely to exceed 15%.
na = not applicable; KOH flux and Ni crucible or Na_2O_2 flux and Zr crucible for fusion preparations, or Si for HF assisted digests.

Battelle PNNL/RPG/Inorganic Analysis ... ICPOES Data Report

QC Performance 5/19/2025

Criteria >	≤ 20%	≤ 20%	80%-120%	80%-120%	80%-120%	80%-120%	80%-120%	80%-120%	80%-120%	75%-125%	75%-125%	75%-125%	75%-125%	75%-125%	75%-125%	80%-120%	80%-120%	80%-120%	80%-120%	≤ 10%	≤ 10%
QC ID >	**25-0752 @25x Dup**	**25-0753 @25x Dup**	**BS-MCVAB LCS/BS**	**25-0752 BS-A @10x LCS/BS**	**25-0752 BS-B @10x LCS/BS**	**25-0752 BS-C @10x LCS/BS**	**25-0753 BS-A @10x LCS/BS**	**25-0753 BS-B @10x LCS/BS**	**25-0753 BS-C @10x LCS/BS**	**25-0752 MS-A @25x MS**	**25-0752 MS-B @25x MS**	**25-0752 MS-C @25x MS**	**25-0753 MS-A @25x MS**	**25-0753 MS-B @25x MS**	**25-0753 MS-C @25x MS**	**PSA-0752 @25x + PS-A**	**PSB-0754 @25x + AS-B**	**PSA-0753 @25x + PS-A**	**PSB-0754 @25x + AS-B**	**25-0752 @125x 5-fold Serial Dil**	**25-0753 @125x 5-fold Serial Dil**
Analytes	**RPD (%)**	**RPD (%)**	**%Rec**	**%Rec**	**%Rec**	**%Rec**	**%Rec**	**%Rec**	**%Rec**	**%Rec**	**%Rec**	**%Rec**	**%Rec**	**%Rec**	**%Rec**	**%Rec**	**%Rec**	**%Rec**	**%Rec**	**%Diff**	**%Diff**
Al	2.3	1.6	99	93			95			93			92			96		105		0.4	3.7
As			91			89			93			89			77	91		94			
Ba			99	92			93			95			94			96		100			
Ca			98	89			90			93			94			97		98			
Cd			98	91			94			99			97			101		101			
Cr	2.0	0.7	94	88			89			nr			nr			95		95		2.1	2.4
Fe			99	92			92			96			94			95		101			
K	2.4	1.2	97	90			90			nr			nr			96		100		4.2	1.5
Na	2.6	1.4	100	91			91			nr			nr			90		116		2.4	6.2
Ni			100	92			93			95			95			97		99			
P			99		95			95			93			91		98		101			
Pb			93	90			91			88			94			93		94			
S			94		87			90			94			84			92		88		
Sr			97	86			86			94			93			97		98			
Ti			104		100			99			103			103		100		104			
U			95	88			90			91			92				97		98		
Zn			94	114			110			78			91			103		105			
Zr			104		100			102			103			105		101		106			
Other Analytes																					
Ag			90													89		90			
B			99		95			96			97			98		98		99			
Be	1.2	1.1	95	88			90			93			93			94		95			
Bi			90													88		92			
Ce			88	84			87			89			89				90		90		
Co			97													95		97			
Cu			106	106			110			111			112			102		103			
Dy			91														95		95		
Eu			91														93		93		
La			90	86			88			88			89				93		92		
Li			105	97			98			96			98			101		104			
Mg			100	94			95			95			98			99		102			
Mn			102	93			94			94			95			99		100			
Mo			101		94			95			98			99		97		101			
Nd			89	85			88			87			88				92		92		
Pd			88														89		89		
Rh			90														92		92		
Ru			89														90		89		
Sb			93													90		93			
Se			106													104		100			
Si			98								63			67		94		99			
Sn			102													98		102			
Ta			105													101		104			
Te			93														93		91		
Th			92	87			88			86			90				94		94		
Tl			89													90		88			
V			95	87			89			90			89			95		95			
W			101													98		103			
Y			94													94		97			

Shaded results are outside the acceptance criteria.

nr = spike concentration less than 25% of sample concentration. Matrix effects can be assessed from the serial dilution.

na = not applicable; KOH flux and Ni crucible or Na_2O_2 flux and Zr crucible for fusion preparations, or Si for HF assisted digests.

Client	**Westesen**												
Work Order #			**Activity**	**6999, Water Leach of Sludge, Soil, and Other Solids**									
ASR #	**2256**		**Analysis**	**IC**									
25-0752	TI180-COMP-FEED	AW-105	IC										
25-0753	TI180-COMP-Eff	AW-105											
	Analyst	Leah Arrigo	Leah Arrigo	Leah Arrigo	Leah Arrigo								
	Date	5/14/2025	5/14/2025	5/14/2025	5/14/2025								
	Balance ID:	21308482	21308482	21308482	21308482								
	Temp. (^{o}C):		21.2										
	Pipette ID:												
		Tare	**w/ Sample**	**w/ Spike**	**w/ Water**				**Sample**	**Spike**	**Water**	**Total Sample**	**Process**
RPL Sample ID	**Client sample ID**	**Weight (g)**	**Weight (g)**	**Weight (g)**	**Weight (g)**		**Contact Times for All Samples**		**Weight (g)**	**Weight (g)**	**Mass (g)**	**Mass (g)**	**Dil Factor**
			0.1 mL	**2 mL**	**7.9 mL or 9.9 mL**								
25-0752	TI180-COMP-FEED	8.7279	8.8537		18.5185	**Time Water Added**	5/14/2025 10:29		0.1258		9.6648	9.7906	77.83
25-0753	TI180-COMP-EFF	8.5981	8.7291		18.4328	**Time Filtered**	5/14/2025 10:39		0.1310		9.7037	9.8347	75.07
25-0753 dup		8.5669	8.6970		18.4263	**Time Stir Bars Added**	N/A		0.1301		9.7293	9.8594	75.78
25-0753 MS		8.5888	10.7437	10.6141	18.5177	**Time Stirring Started**	N/A		0.1296	2.0253	7.7740	9.9289	76.61
25-0753 BS		8.6303		10.6518	18.5337	**Time Stirring Stopped**	N/A			2.0215	7.8819	9.9034	
25-0753 PB		8.6454			18.5117	**Full Contact Time (hr)**	0:10				9.8663	9.8663	
	Spike ID	**Lot**	**Expiration Date**	**Vendor**									
Spike A:	**IV-Stock-59**	T2-MEB717227	1/27/2026	Inorganic Ventures	**Anions Cal Std 20 ppm**								
	Manufacturer	**Lot/Batch**	**Part Number**	**Material**	**Description**								
Syringe	BD			poly	10 mL, prepackaged								
Syringe Filter	Fisher	1912315854		0.45 um PVDF	22 mm diameter								

Analyst/Date: Leah M Arrigo Digitally signed by Leah M Arrigo Date: 2025.07.24 10:59:04 -07'00'

Reviewer/Date: Catalin Harabagiu Digitally signed by Catalin Harabagiu Date: 2025.07.24 11:05:35 -07'00'

Veronika Deskins Digitally signed by Veronika Deskins Date: 2025.07.24 13:15:56 -07'00'

Client	**Westesen**								
Work Order #			**Activity**	6999, "Water leach of sludge, soil, and other solids"					
ASR #	**2256**		**Analysis**	TIC/TOC					
RPL Sample ID	**Client sample ID**								
25-0752	TI180-COMP-FEED	AW-105	TIC/TOC						
25-0753	TI180-COMP-Eff	AW-105							
	Analyst	Leah Arrigo	Leah Arrigo	Leah Arrigo					
	Date	5/14/2025	5/14/2025	5/14/2025					
	Balance ID:	21308482	21308482	21308482					
	Temp. (^{o}C):		21.2	21.2					
	Pipette ID:		P34412H	O429691					
RPL Sample ID	**Client sample ID**	**Tare Weight (g)**	**w/ Water Weight (g)**	**w/ Sample Weight (g)**		**Sample Weight (g)**	**Water Mass (g)**	**Water Volume (mL)**	**Process Dil Factor**
			9 mL	**1 mL**					
25-0752	TI180-COMP-FEED	15.5296	25.6765	16.7748		1.2452	8.9017	8.9196	8.15
25-0753	TI180-COMP-Eff	15.9692	26.0407	17.1816		1.2124	8.8591	8.8769	8.31
25-0752 Blank		15.5806	25.4218				9.8412	9.8610	

Notes: **10X dilution in DDI water for a final solution volume of 10 mL; samples were not filtered after mixing with H2O.**

Analyst/Date: Leah M Arrigo Digitally signed by Leah M Arrigo
Date: 2025.07.23 16:10:11 -07'00'

Reviewer/Date: Catalin Harabagiu Digitally signed by Catalin Harabagiu
Date: 2025.07.24 11:05:14 -07'00'

QE review/Date: Jennifer Bauman Digitally signed by Jennifer Bauman
Date: 2025.07.24 12:38:40 -07'00'

Elsa
Cordova/3K022

Digitally signed by Elsa
Cordova/3K022
Date: 2025.07.21
12:04:51 -07'00'

SXDATA

LabNumber	SampleName	Analyte	Result	Units	EQL
2506006-01	25-0721	Bromide	ND	ug/mL	0.860
2506006-01	25-0721	Chloride	11.2	ug/mL	0.480
2506006-01	25-0721	Fluoride	ND	ug/mL	0.460
2506006-01	25-0721	Nitrate	2430	ug/mL	1.22
2506006-01	25-0721	Nitrite	112	ug/mL	1.42
2506006-01	25-0721	Phosphate	136	ug/mL	2.55
2506006-01	25-0721	Sulfate	63.5	ug/mL	0.940
2506006-01	25-0721	Total Carbon	1040	ug/mL	40.0
2506006-01	25-0721	Total Organic Carbon	56.1	ug/mL	40.0
2506006-02	25-0722	Bromide	ND	ug/mL	0.860
2506006-02	25-0722	Chloride	18.6	ug/mL	0.480
2506006-02	25-0722	Fluoride	ND	ug/mL	0.460
2506006-02	25-0722	Nitrate	2230	ug/mL	1.22
2506006-02	25-0722	Nitrite	280	ug/mL	1.42
2506006-02	25-0722	Phosphate	20.1	ug/mL	2.55
2506006-02	25-0722	Sulfate	79.8	ug/mL	0.940
2506006-02	25-0722	Total Carbon	607	ug/mL	40.0
2506006-02	25-0722	Total Organic Carbon	69.0	ug/mL	40.0
2506006-03	25-0752	Bromide	ND	ug/mL	0.860
2506006-03	25-0752	Chloride	17.2	ug/mL	0.480
2506006-03	25-0752	Fluoride	14.3	ug/mL	0.460
2506006-03	25-0752	Nitrate	1050	ug/mL	1.22
2506006-03	25-0752	Nitrite	457	ug/mL	1.42
2506006-03	25-0752	Phosphate	ND	ug/mL	2.55
2506006-03	25-0752	Sulfate	34.2	ug/mL	0.940
2506006-03	25-0752	Total Carbon	1060	ug/mL	40.0
2506006-03	25-0752	Total Organic Carbon	148	ug/mL	40.0
2506006-04	25-0753	Bromide	ND	ug/mL	0.860
2506006-04	25-0753	Chloride	18.1	ug/mL	0.480
2506006-04	25-0753	Fluoride	14.6	ug/mL	0.460
2506006-04	25-0753	Nitrate	1090	ug/mL	1.22
2506006-04	25-0753	Nitrite	474	ug/mL	1.42
2506006-04	25-0753	Phosphate	ND	ug/mL	2.55
2506006-04	25-0753	Sulfate	35.8	ug/mL	0.940
2506006-04	25-0753	Total Carbon	1030	ug/mL	40.0
2506006-04	25-0753	Total Organic Carbon	149	ug/mL	40.0
2506006-05	25-0721 PB	Bromide	ND	ug/mL	0.860
2506006-05	25-0721 PB	Chloride	ND	ug/mL	0.480
2506006-05	25-0721 PB	Fluoride	ND	ug/mL	0.460
2506006-05	25-0721 PB	Nitrate	ND	ug/mL	1.22
2506006-05	25-0721 PB	Nitrite	ND	ug/mL	1.42
2506006-05	25-0721 PB	Phosphate	ND	ug/mL	2.55
2506006-05	25-0721 PB	Sulfate	ND	ug/mL	0.940
2506006-06	25-0721 BS	Bromide	206	ug/mL	0.860
2506006-06	25-0721 BS	Chloride	218	ug/mL	0.480
2506006-06	25-0721 BS	Fluoride	226	ug/mL	0.460
2506006-06	25-0721 BS	Nitrate	210	ug/mL	1.22
2506006-06	25-0721 BS	Nitrite	222	ug/mL	1.42
2506006-06	25-0721 BS	Phosphate	210	ug/mL	2.55
2506006-06	25-0721 BS	Sulfate	206	ug/mL	0.940
2506006-07	25-0721 MS	Bromide	200	ug/mL	0.860

SXDATA

2506006-07	25-0721 MS	Chloride	220	ug/mL	0.480
2506006-07	25-0721 MS	Fluoride	220	ug/mL	0.460
2506006-07	25-0721 MS	Nitrate	2660	ug/mL	1.22
2506006-07	25-0721 MS	Nitrite	320	ug/mL	1.42
2506006-07	25-0721 MS	Phosphate	331	ug/mL	2.55
2506006-07	25-0721 MS	Sulfate	262	ug/mL	0.940
2506006-08	25-0721 Dup	Bromide	ND	ug/mL	0.860
2506006-08	25-0721 Dup	Chloride	11.1	ug/mL	0.480
2506006-08	25-0721 Dup	Fluoride	ND	ug/mL	0.460
2506006-08	25-0721 Dup	Nitrate	2450	ug/mL	1.22
2506006-08	25-0721 Dup	Nitrite	114	ug/mL	1.42
2506006-08	25-0721 Dup	Phosphate	138	ug/mL	2.55
2506006-08	25-0721 Dup	Sulfate	66.8	ug/mL	0.940
2506006-09	25-0721 Blk	Total Carbon	ND	ug/mL	40.0
2506006-09	25-0721 Blk	Total Organic Carbon	ND	ug/mL	40.0
2506006-10	25-0752 Blk	Total Carbon	ND	ug/mL	40.0
2506006-10	25-0752 Blk	Total Organic Carbon	ND	ug/mL	40.0
2506006-11	25-0753 PB	Bromide	ND	ug/mL	0.860
2506006-11	25-0753 PB	Chloride	ND	ug/mL	0.480
2506006-11	25-0753 PB	Fluoride	ND	ug/mL	0.460
2506006-11	25-0753 PB	Nitrate	ND	ug/mL	1.22
2506006-11	25-0753 PB	Nitrite	ND	ug/mL	1.42
2506006-11	25-0753 PB	Phosphate	ND	ug/mL	2.55
2506006-11	25-0753 PB	Sulfate	ND	ug/mL	0.940
2506006-12	25-0753 BS	Bromide	199	ug/mL	0.860
2506006-12	25-0753 BS	Chloride	212	ug/mL	0.480
2506006-12	25-0753 BS	Fluoride	219	ug/mL	0.460
2506006-12	25-0753 BS	Nitrate	203	ug/mL	1.22
2506006-12	25-0753 BS	Nitrite	219	ug/mL	1.42
2506006-12	25-0753 BS	Phosphate	207	ug/mL	2.55
2506006-12	25-0753 BS	Sulfate	200	ug/mL	0.940
2506006-13	25-0753 MS	Bromide	195	ug/mL	0.860
2506006-13	25-0753 MS	Chloride	225	ug/mL	0.480
2506006-13	25-0753 MS	Fluoride	221	ug/mL	0.460
2506006-13	25-0753 MS	Nitrate	1250	ug/mL	1.22
2506006-13	25-0753 MS	Nitrite	664	ug/mL	1.42
2506006-13	25-0753 MS	Phosphate	198	ug/mL	2.55
2506006-13	25-0753 MS	Sulfate	226	ug/mL	0.940
2506006-14	25-0753 Dup	Bromide	ND	ug/mL	0.860
2506006-14	25-0753 Dup	Chloride	17.3	ug/mL	0.480
2506006-14	25-0753 Dup	Fluoride	14.7	ug/mL	0.460
2506006-14	25-0753 Dup	Nitrate	1080	ug/mL	1.22
2506006-14	25-0753 Dup	Nitrite	469	ug/mL	1.42
2506006-14	25-0753 Dup	Phosphate	ND	ug/mL	2.55
2506006-14	25-0753 Dup	Sulfate	35.5	ug/mL	0.940

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Appendix C – Batch Contact Results

Table C.1 presents the experimental results used to produce the AW-105 Cs distribution coefficient (K_d) curves and isotherms at four contact temperatures (Figure 4.7 and Figure 4.8 in the main body of this report). The dry crystalline silicotitanate (CST) masses were based on an F-factor of 0.9478 at the nominal drying temperature of 105 °C.

Table C.1. AW-105 Tank Waste Isotherm Data

Sample ID	Dry CST Mass (g)	AW-105 Vol. (mL)	Initial Cs Conc. (µg/mL)	Equil. Cs Conc. (M)	K_d (mL/g)	Q (mmoles Cs/g)
13.4 °C						
TI181-S1-13	0.0747	14.5434	20.8	2.34E-05	1103	2.59E-02
TI181-S1-13d	0.0759	14.3649	20.8	2.38E-05	1051	2.51E-02
TI181-S2-13	0.0746	14.5261	61.6	7.56E-05	997	7.56E-02
TI181-S2-13d	0.0749	14.5317	61.6	7.67E-05	979	7.51E-02
TI181-S3-13	0.0749	14.4562	205.8	3.66E-04	627	2.28E-01
TI181-S3-13d	0.0754	14.4628	205.8	3.24E-04	721	2.35E-01
TI181-S4-13	0.0746	14.5226	2179.0	1.26E-02	58	7.36E-01
TI181-S4-13d	0.0743	14.5264	2179.0	1.29E-02	52	6.74E-01
15.7 °C						
TI181-S1-16	0.0748	14.6150	20.8	2.53E-05	1013	2.56E-02
TI181-S1-16d	0.0747	14.6402	20.8	2.53E-05	1013	2.57E-02
TI181-S2-16	0.0758	14.4509	61.6	7.78E-05	943	7.35E-02
TI181-S2-16d	0.0748	14.3951	61.6	7.60E-05	980	7.46E-02
TI181-S3-16	0.0755	14.6801	205.8	3.81E-04	591	2.27E-01
TI181-S3-16d	0.0748	14.6548	205.8	3.88E-04	588	2.28E-01
TI181-S4-16	0.0746	14.5049	2179.0	1.25E-02	60	7.56E-01
TI181-S4-16d	0.0745	14.4400	2179.0	1.28E-02	54	7.03E-01
24.8 °C						
TI181-S1-25	0.0750	14.4744	20.8	3.38E-05	698	2.37E-02
TI181-S1-25d	0.0750	14.2121	20.8	3.21E-05	733	2.36E-02
TI181-S2-25	0.0755	14.5644	61.6	9.96E-05	694	7.02E-02
TI181-S2-25d	0.0755	14.5329	61.6	9.92E-05	710	7.01E-02
TI181-S3-25	0.0754	14.4350	205.8	4.12E-04	527	2.18E-01
TI181-S3-25d	0.0754	14.3894	205.8	4.19E-04	515	2.16E-01
TI181-S4-25	0.0750	14.5808	2179.0	1.20E-02	70	8.48E-01
TI181-S4-25d	0.0753	14.5260	2179.0	1.23E-02	63	7.92E-01
25.1 °C – Hot cell						
TI181-S0-HC-25	0.0747	14.8530	5.5	1.02E-05	602	6.15E-03
TI181-S0-HC-25d	0.0752	14.8641	5.5	1.04E-05	582	6.07E-03
TI181-S2-HC-25	0.0745	14.8048	62.7	1.24E-04	556	6.91E-02
TI181-S2-HC-25d	0.0759	15.0563	62.7	1.24E-04	550	6.89E-02
TI181-S3-HC-25	0.0746	14.8433	202.6	5.04E-04	400	2.03E-01
TI181-S3-HC-25d	0.0749	15.0549	202.6	4.80E-04	432	2.10E-01
TI181-S4-HC-25	0.0748	14.7932	2018.2	1.22E-02	48	5.91E-01
TI181-S4-HC-25d	0.0747	15.4132	2018.2	1.24E-02	46	5.78E-01
33.2 °C						
TI181-S1-35	0.0757	14.7198	20.8	4.24E-05	520	2.20E-02
TI181-S1-35d	0.0749	15.1562	20.8	3.75E-05	618	2.32E-02
TI181-S2-35	0.0752	15.0061	61.6	1.27E-04	512	6.50E-02
TI181-S2-35d	0.0754	15.0476	61.6	1.22E-04	532	6.55E-02
TI181-S3-35	0.0749	15.0992	205.8	5.28E-04	379	2.00E-01
TI181-S3-35d	0.0758	15.0686	205.8	4.90E-04	412	2.04E-01
TI181-S4-35	0.0757	15.0412	2179.0	1.20E-02	69	8.37E-01
TI181-S4-35d	0.0746	15.0278	2179.0	1.10E-02	96	1.05E+00

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