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PNNL-34671, Rev. 0
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Cesium Removal from SY-101 Tank Waste Using Crystalline Silicotitanate

September 2023

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U.S. DEPARTMENT OF ENERGY

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

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Summary

The newly operational Tank Side Cesium Removal (TSCR) system removes radioactive cesium-137 (^{137}Cs) and solids from tank waste supernate in the 200 east area of the Hanford site. Efforts to expand the removal capabilities to the 200 west area are underway by a system anticipated to be called the West Area Risk Management (WARM) system.

Laboratory-scale ion exchange processing using expected WARM unit operations were conducted to contribute toward Washington River Protection Solutions (WRPS) establishing accurate process flowsheets for the individual feed campaigns planned for the west area supernate pretreatment. This report describes the small-scale ion exchange testing with 8.0 L of filtered supernate from tank 241-SY-101 (referred to as SY-101) at 16 °C (62 °F) to demonstrate processing conditions that would be prototypic of what the WARM system may experience.

One of the waste acceptance criteria (WAC) for the Waste Treatment 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 SY-101 tank waste to meet this criterion, only 0.44% of the influent ^{137}Cs concentration may be delivered to the WTP; this requires a Cs decontamination factor of 227. Testing with SY-101 matched current TSCR prototypic operations where a lead-lag configuration is used until the lag column reached the WAC limit. Neither the lead nor lag columns reached the WAC, so a polish column was never utilized during this test. Feed was processed at 1.9 bed volumes (BVs) per hour; the flowrate, in terms of contact time with the crystalline silicotitate (CST) bed, matched the current flowrate at TSCR (an expected flowrate to be used at WARM).

The lead column only reached 0.09% Cs breakthrough after processing ~1363 BVs of feed. Cesium breakthrough from the lag column was not observed during the entire processing. Table S.1 and Figure S.1 summarize the observed column performance and relevant Cs loading characteristics. Table S.1 and Figure S.1 also summarize the measured SY-101 Cs load performance.

Table S.1. SY-101 Column Performance Summary with CST

Column	WAC Limit Breakthrough (BVs)	50% Cs Breakthrough (BVs)	^{137}Cs Loaded (μCi/g)	Cs Loaded (mmoles/g CST)
Lead	1664[(a)]	4944[(a)]	26,421	0.0166
Lag	NA	NA	1,791	0.0011

(a) Extrapolated value
BV = bed volume, 6 mL
The time weighted average flowrate was 1.9 BV/h.

[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.

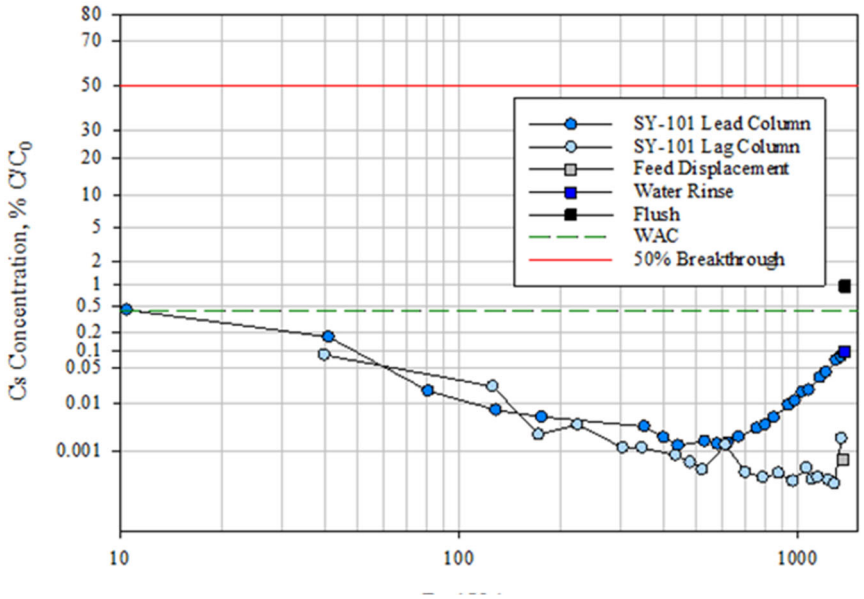


Figure S.1. Column Cs Load Profiles for SY-101

Batch contact tests were performed with the SY-101 tank waste at four Cs concentrations, each at a phase ratio of 200 (liquid volume to dry CST mass). The distribution coefficient (K_d) at the equilibrium condition of 1.29E-5 M Cs was 4928 mL SY-101/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 4928 BVs. The predicted column 50% Cs breakthrough (4944 BVs) was within 1% of the predicted performance from batch contact testing (4928 BVs). The batch contact testing predicted a Cs load capacity of 0.0636 mmoles Cs/g dry CST at the equilibrium Cs concentration. The Cs breakthrough from the lead column at the predicted 50% breakthrough value was determined to be 0.0638 mmoles Cs/ g CST – 99.6% of the maximum Cs loading at feed condition based on prediction from batch contact testing.

The SY-101 composite feed and composite effluent were characterized to understand the fractionation of selected metals and radionuclides. Concentrations and recoveries of the selected analytes are summarized in Table S.2; those with low recovery were assumed to be adsorbed onto CST. Large fractions of calcium (Ca), lead (Pb), nickel (Ni), neptunium (Np), plutonium (Pu), and americium (Am) significantly fractionated to the CST.

Table S.2. Recoveries of Analytes of Interest in the SY-101 Effluent

	Analyte	Feed Concentration (M)	Effluent Concentration (M)	Fraction in Effluent
Metals / Non-metals	Al	1.42E-01	1.32E-01	91%
	B	1.18E-03	9.90E-04	82%
	Ca	3.44E-04	1.37E-04	39%
	Cr	2.30E-03	2.17E-03	93%
	Pb	9.19E-06	5.46E-06	58%
	Mo	1.19E-04	1.13E-04	94%
	Ni	3.98E-05	2.20E-05	54%
	P	8.69E-02	8.13E-02	92%
	K	1.02E-02	9.34E-03	91%
	Si	1.21E-03	8.56E-04	70%
	Na	2.96E+00	2.85E+00	95%
	S	2.58E-02	2.45E-02	94%
	Sn	2.83E-05	2.61E-05	91%
	W	1.06E-04	1.05E-04	97%
	Analyte	Feed Concentration (µCi/mL)	Effluent Concentration (µCi/mL)	Fraction in Effluent
Radionuclides	^{137}Cs	9.10E+01	2.41E-02	0.03%
	^{237}Np	2.22E-06	1.49E-07	7%
	^{238}Pu	1.60E-05	5.17E-06	32%
	$^{239+240}$Pu	8.76E-05	2.52E-05	28%
	^{241}Am	1.70E-04	7.78E-05	45%

Notes:
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.

Acknowledgements

The authors thank Shielded Facility Operations staff Victor Aguilar, Hollan Brown, and Robert Cox for hot cell operations (ion exchange column system setup, processing, and sample removal). We thank the Analytical Support Operations (ASO) staff Leah Arrigo, Steven Baum, Lori Darnell, Sam Morrison, Christian Perez, Matthew Risenhuber, and Dave Blanchard for the sample analysis, data processing, and reporting. The authors thank 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 this report and Matt Wilburn for his technical editing contribution to this report.

Acronyms and Abbreviations

ASO	Analytical Support Operations
ASR	Analytical Service Request
BV	bed volume
CST	crystalline silicotitanate
DF	decontamination factor
DI	deionized
DOE	Department of Energy
EQL	estimated quantitation limit
erf	error function
FD	feed displacement
GEA	gamma energy analysis
IC	ion chromatography
ICP-MS	inductively coupled plasma mass spectrometry
ICP-OES	inductively coupled plasma optical emission spectroscopy
ID	identification
LAW	low-activity waste
MDL	method detection limit
NA	not applicable
PNNL	Pacific Northwest National Laboratory
QA	quality assurance
R&D	research and development
SV	system volume
SwRI	Southwest Research Institute
TIC	total inorganic carbon
TOC	total organic carbon
TRU	transuranic
TSCR	Tank Side Cesium Removal
WAC	waste acceptance criteria
WARM	West Area Risk Management
WRPS	Washington River Protection Solutions, LLC
WTP	Hanford Waste Treatment and Immobilization Plant
WWFTP	WRPS Waste Form Testing Program

Contents

Figures

Tables

1.0 Introduction

The newly operational Tank Side Cesium Removal (TSCR) system removes radioactive cesium-137 (^{137}Cs) and solids from tank waste supernate in the 200 east area of the Hanford site. The Department of Energy (DOE) intends to expand these Cs removal capabilities to the 200 west area by initiating the West Area Risk Management (WARM) system. The expansion of removal capabilities to the west area are necessary to provide treated low-activity waste (LAW) streams to the Hanford Waste Treatment and Immobilization Plant (WTP) as well as free up space for further retrievals from the 200 west area single shell tanks once the facility comes online. The planned WARM system will be a successor to the TSCR project serving the direct feed LAW portion of the WTP mission. Tank waste supernate processed through WARM will be required to meet the WTP LAW Facility waste acceptance criteria (WAC). Specific to ^{137}Cs, this requirement is <3.18E-5 Ci ^{137}Cs/mole of Na.[2] The key process operations for treating the waste are intended to include solids filtration and cesium removal. Anticipated to mimic the current TSCR design, WARM will likely use a dead-end filtration system for solids removal and crystalline silicotitanate (CST), a non-elutable ion exchange material, for cesium removal.

Seven demonstrations of laboratory-scale ion exchange processing using TSCR prototypic unit operations have contributed towards Amentum-led Washington River Protection Solutions (WRPS) establishing accurate process flowsheets for individual feed campaigns, with a primary focus on tanks in AP farm that contain significant quantities of supernate. Efforts to expand feed campaigns from the 200 east area to the 200 west area require an evaluation of unit operation process steps to include new tank chemistries. As the largest source of supernate currently available in the 200-west area, 241-SY-101 (hereafter called SY-101) tank waste was collected and processed through the Radioactive Waste Test Platform at Pacific Northwest National Laboratory (PNNL).

Approximately 8 L of Hanford tank waste supernate were collected from tank 241-SY-101. Figure 1.1 shows a temperature profile of the SY-101 supernate between January 2021 and December 2022; the temperature averaged 19.6 °C with a range of 18.1 to 21.4 °C. To match previous laboratory-scale ion exchange testing, an operating temperature of 16 °C was established for this SY-101 testing. Operating at the lower range of temperatures will help to predict the maximum ^{137}Cs loading onto the CST and guide the appropriate operating restrictions to ensure the column loading limit will not be exceeded.

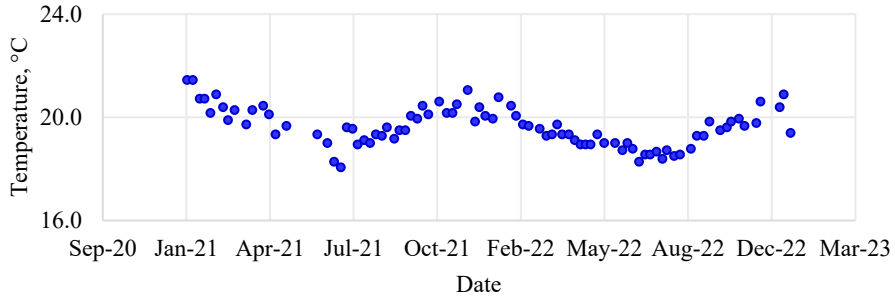


Figure notes: Data collected from 241-SY-101 Location Riser 1 17B.
Data downloaded from Tank Waste Information Network System on March 3, 2023.

Figure 1.1. SY-101 Tank Waste Temperatures from January 2021 to December 2022

[2] 24590-WTP-ICD-MG-01-030, Rev. 1. 2017. *ICD 30 – Interface Control Document for Direct LAW Feed.* Bechtel National, Inc., Richland, Washington.

This report discusses the results of SY-101 testing using CST in a lead-lag column format at 16 °C. A determination of radionuclide, cation, and anion mass balances (with special emphasis on Cs, Pu, and Na) as a function of supernate volume processed were conducted. Cesium capacity as a function of temperature at 13, 16, 21, and 35 °C were also determined at 6 different Cs concentrations using batch contacts.

WRPS funded PNNL to conduct testing with SY-101 tank waste under the Task 3 of the WRPS statement of work.[3] There are no deviations from the statement of work.

[3] Rad Waste Test Platform Processing of SY-101 Sample, Requisition # 3262276 Rev. 0 Statement of Work. November 1 2022. Not publicly available. Washington River Protection Solutions, Richland, Washington.

2.0 Quality Assurance

All research and development (R&D) work at PNNL is performed in accordance with PNNL's Laboratory-Level Quality Management Program, which is based on a graded application of NQA-1-2000, *Quality Assurance Requirements for Nuclear Facility Applications* (ASME 2000), to R&D activities. To ensure that all client quality assurance (QA) expectations were addressed, the QA controls of the PNNL's WRPS Waste Form Testing Program (WWFTP) QA program were also implemented for this work. The WWFTP QA program implements the requirements of NQA-1-2008, *Quality Assurance Requirements for Nuclear Facility Applications* (ASME 2008), and NQA-1a-2009, *Addenda to ASME NQA-1-2008* (ASME 2009), and consists of the WWFTP Quality Assurance Plan (QA-WWFTP-001) and associated QA-NSLW-numbered procedures that provide detailed instructions for implementing NQA-1 requirements for R&D work.

The work described in this report was assigned the technology level "Applied Research" and was planned, performed, documented, and reported in accordance with procedure QA-NSLW-1102, *Scientific Investigation for Applied Research*. All staff members contributing to the work received proper technical and QA training prior to performing quality-affecting work.

3.0 Test Conditions

This section describes the CST media, SY-101 tank waste, column ion exchange conditions, sample analysis, and batch contact conditions. All testing was conducted in accordance with a test plan prepared by PNNL and approved by WRPS.[4]

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,[5] 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. 2019b). Before use in column and batch contact testing, the <30-mesh CST fraction was first pretreated by contacting with 0.1 M NaOH successively until fines were no longer observed.

3.2 SY-101 Tank Waste Sample

Multiple samples (32 each at nominally 250 mL) were collected at six different depths (26 in., 81 in., 135 in., 187 in., 240 in., and 294 in. below supernate surface) from Hanford tank SY-101 in December 2022. The waste was composited into 7 individual feed bottles by combining 200 mL from each sample depth into 1.5 L bottles. A pro-rated volume was taken from each of the 7 bottles and composited for a limited analysis suite. The density was measured in cell using a 10-mL volumetric flask. All other measurements were conducted by the Analytical Support Operations (ASO) according to Analytical Service Request (ASR) 1673; results are provided in Table 3.1.

Table 3.1. Characterization of Composite SY-101 Sample (ASR 1673)

Analyte	Result	Result Units	Analysis Method
Al	0.135	M	ICP-OES
K	0.010	M	ICP-OES
Na	2.43	M	ICP-OES
^{133}Cs	1.25	µg/mL	ICP-MS
^{137}Cs	20.6 (a)	µCi/mL	GEA
^{137}Cs	1.73 (a)	µg/mL	GEA
Density	1.140 (b)	g/mL	Volumetric flask

(a) Reference date is March 28, 2023.
(b) Measured at 24.5 °C using a 10-mL volumetric flask.
ASR 1673, sample 23-0331 and 23-0329, see Appendix B.
GEA = gamma energy analysis; ICP-MS = inductively coupled plasma mass spectrometry; ICP-OES = inductively coupled plasma optical emission spectroscopy

[4] Westesen AM. 2023. Test Plan TP-DFTP-146, Rev. 0.0. *FY23 Cesium Ion Exchange Testing with SY-101 Tank Waste Using Crystalline Silicotitanate Media.* Pacific Northwest National Laboratory, Richland, Washington. Not publicly available.

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

The Cs isotopic composition of the SY-101 was measured to determine the total Cs concentration in the supernate. Except for ^{133}Cs, direct analysis of SY-101 for the ^{135}Cs and ^{137}Cs isotopes can result in isobaric interferences. Therefore, a subsample of the composite analysis sample was processed to isolate Cs. An aliquot (1.5 mL) of SY-101 was batch contacted with 2 mL Na-form spherical resorcinol-formaldehyde (sRF) resin suspended in 8 mL 1 M NaOH. The slurry was 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 0.1 M NaOH, then rinsed three times with 6 mL deionized water. Cesium 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 provided in Table 3.2. The total Cs concentration was calculated from the GEA-measured ^{137}Cs and the ICP-MS-measured isotopic composition. The calculated ^{133}Cs concentration agreed within 6% of the ICP-MS-measured ^{133}Cs concentration (shown in Table 3.2). The total Cs concentration in the SY-101 was 1.73 µg/mL or 1.29E-5 M.

Table 3.2. SY-101 Average Cs Isotopic Composition (ASR 1673)

Analyte[a]	1SY-23-Comp-Cs Results	Units
Cs isotopic mass ratio[a,b,c]	72.3	wt% ^{133}Cs
	14.0	wt% ^{135}Cs
	13.7	wt% ^{137}Cs
Total Cs	1.73	µg/mL Cs

(a) The Cs eluate samples (SY-Comp-Cs-1 and SY-Comp-Cs-2) were analyzed for the Cs isotopic mass distribution by ICP-MS per ASR 1673 sample ID 23-0329, see Appendix B.
(b) Reference date is April 13, 2023.
(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.

3.3 Ion Exchange Column Processing

The ion exchange process system has been previously described (Westesen et al. 2023); a system, schematic for processing downflow lead column to lag column is reproduced in Figure 3.1. The quick disconnect valves were aligned to alter the fluid flow path downflow from lag column to lead column. Lead column samples were collected at valve 2 and lag column samples were collected from valve 3 during the SY-101 loading process. The gross SY-101 effluent, feed displacement (FD), water rinse, and flushed fluid were collected at the effluent line. The valve manifold was the same as the one used previously for 5.5 and 7 M Na AP-105 processing reported in Westesen et al. (2023).

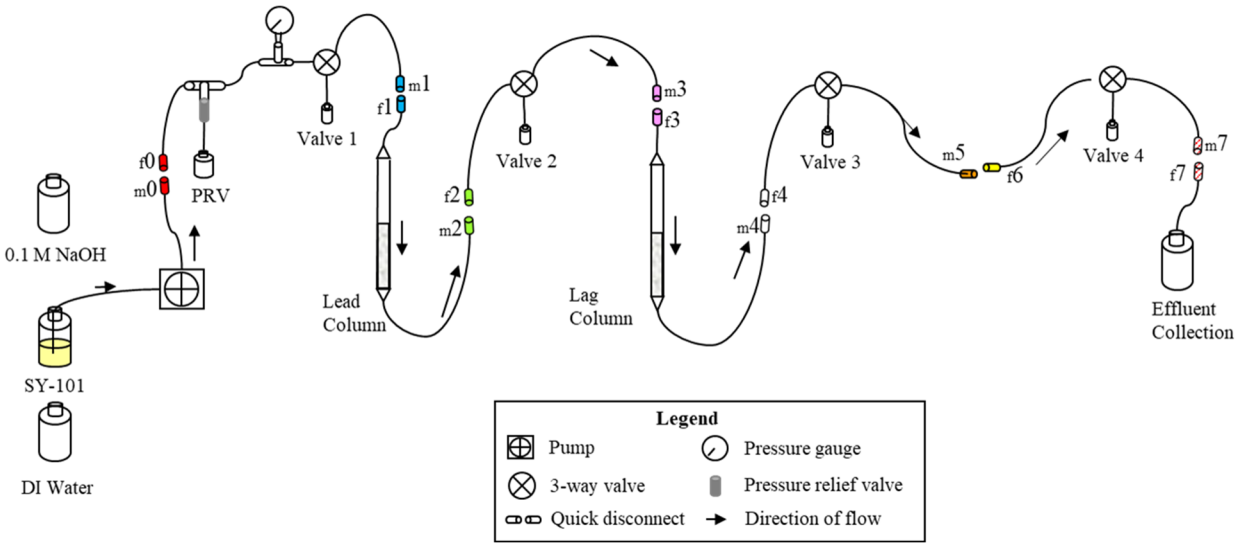


Figure 3.1. Cesium Ion Exchange Process Schematic Lead-to-Lag Processing

Westesen et al. (2023) also described the CST pretreatment steps. As a reminder, the bed volume (BV) corresponds to the initial settled CST BV as measured in a graduated cylinder prior to transferring the media into the ion exchange columns. The reference CST BVs for this testing is 6 mL for both the lead and lag columns. A photograph of the in-cell SY-101 system is shown in Figure 3.2.

Figure 3.2. SY-101 Ion Exchange Assembly in the Hot Cell

The SY-101 supernate was processed through the ion exchange columns at 16 °C and 1.9 BV/h. A series of SY-101 1.5-L polyethylene containers from the filtration process (Allred et al. 2023) were strategically processed to allow optimal feed volume management and support unattended, off-shift (graveyard) work. Effluent was collected in ~1.3-L increments. This volume limitation allowed for safe transfer out of cell in 1.5-L polyethylene bottles. After the SY-101 processing was completed, ~12 BVs (72 mL) of 0.1 M NaOH FD followed by ~12 BVs of deionized (DI) water were passed downflow through the system to rinse residual feed out of the columns and process lines.

Figure 3.3 provides daily temperature and flowrate profiles of the SY-101 processing as it went through the columns. Temperature was measured using a thermocouple placed inside a vial of water that sat within the exchanger. The exchanger temperature averaged 16.2 °C throughout the testing, with min/max temperatures of 15.7 and 16.9 °C, respectively. The pump head stroke length was close to the minimum at which it could be set. The stroke rate was toggled between 9.9 and 10.0 (maximum fidelity of 0.1 units) to

maintain the flowrate between 1.7 and 2.0 BV/h. Test parameters, including process volumes, flowrates, and CST contact times, are summarized in Table 3.3.

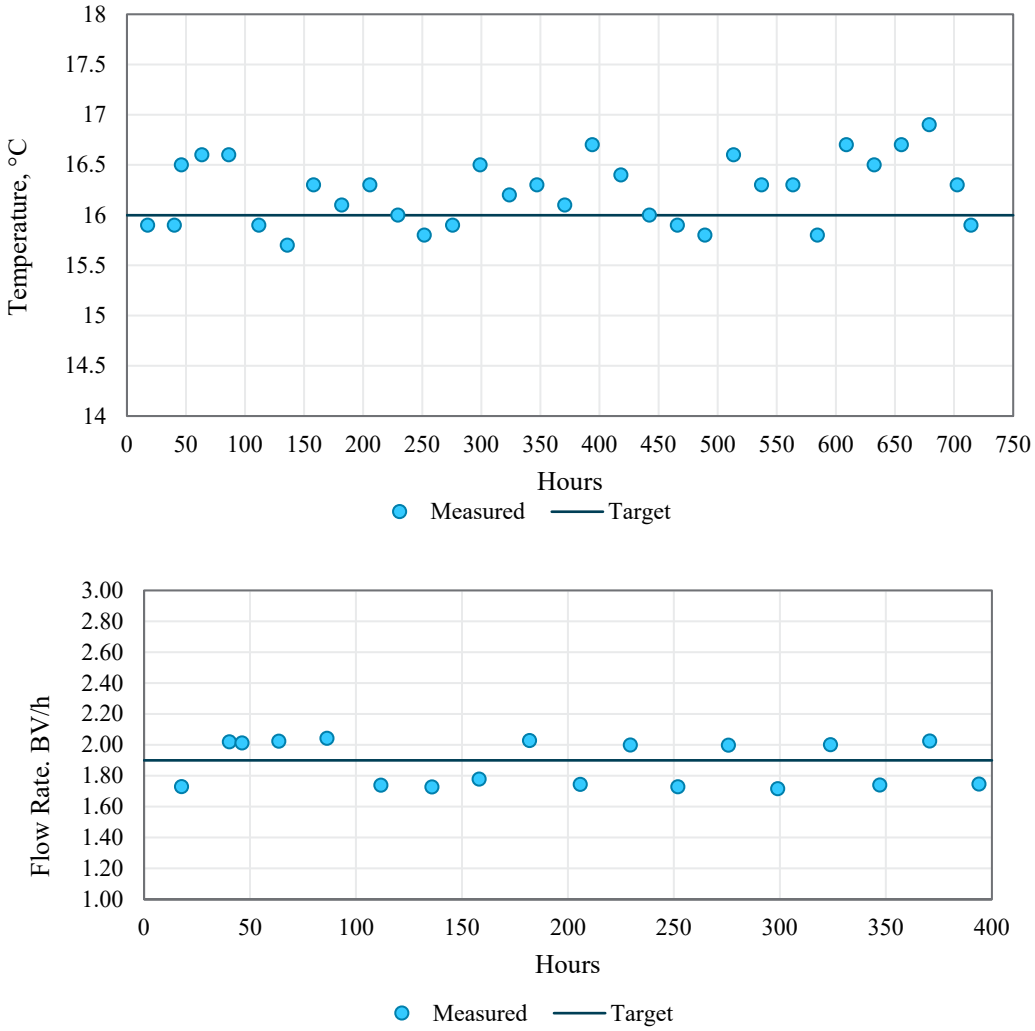


Figure 3.3. SY-101 Daily Column Temperature and Flowrate during Testing

Table 3.3. Experimental Conditions for SY-101 Column Processing at 16 °C, March 27- April 26, 2023

		Volume			Flowrate		Duration
Process Step	Solution	(BV)	(SV)	(mL)	(BV/h)	(mL/min)	(h)
Loading lead column	SY-101	1362.7	NA	8176	1.87	0.187	731
Loading lag column[(a)]	SY-101	1342.4	NA	8054	1.87	0.187	731
Feed displacement	0.1 M NaOH	13.4	1.62	80.4	5.51	0.551	2.5

Water rinse	DI water	13.2	1.60	79.5	3.68	0.368	3.5
Flush with compressed air[(b)]	NA	8.1	0.98	48.8	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 flush occurred on May 2, 2023, after the system sat in static contact with water rinse for a day.
BV = bed volume (6.0 mL as measured in graduated cylinder)
DI = deionized
SV = system volume (estimated 49.8 mL)
NA = not applicable

During the loading phase, nominal 2-mL samples were collected from the lead and lag columns at the sample collection ports (see Figure 3.1valves 2 and 3). Sampling from the columns necessitated brief (~10-minute) interruptions of flow to the downstream columns. Samples were collected after the first 10 BVs were processed and again at nominal 10- to 94-BV increments. Only brief (~5-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 connected at the first quick disconnect in the system in ~10 minutes. The collected volume (48.8 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 such that it would effectively pour out of the columns into specially designed shielded containment for later examination (not addressed in this report). The recovered CST was 6.13 and 6.12 g for the lead and lag columns, respectively. With a CST bed density of 1.00 g/mL, quantitative recovery of the CST from the columns was estimated.

3.4 Batch Contact Conditions

Batch contact experiments with SY-101 effluent following ion exchange processing were conducted to evaluate Cs loading at four different temperatures. Stock solutions of 0.75, 0.086, and 0.038 M $CsNO_3$ were prepared by dissolving the nitrate salt in a volumetric flask and diluted with DI water. Calculated volumes of Cs stock solutions were delivered to poly bottles and the mass of the spike was measured. The SY-101 effluent was spiked with ^{137}Cs, and nominally 125 mL was transferred into each poly bottle to achieve Cs concentrations of 3.5E-5, 7.5E-5, 1.2E-4, 3.4E-4, 8.1E-4, and 1.5E-2 M Cs. The Cs concentration range was expanded upon at the lower end in comparison to previous batch contact testing due to the expected lower Cs concentration in SY-101. 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 sample collection, and used to determine the dry mass of the exchanger. The F-factor was measured at nominally 105 °C with an average value of 0.866. The F-factor at 105 °C measured at the time of the experiment was used to calculate the dry mass of CST for batch contact tests.

Aliquots (15-mL) of the SY-101 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 199 ± 3. The duplicate samples for two concentrations at 35 °C were omitted due to a loss of solution resulting in solution-to-mass ratios of ~135.

The 13 °C and ambient (20 ± 2 °C) batch contact tests were done concurrently. The 20 °C (ambient) samples were contacted on a Cole-Parmer (Vernon Hills, Illinois) large orbital shaker set to 240 rpm. The remaining three temperatures (13, 16, and 35 °C) were sequentially contacted in a Benchmark (Sayreville,

New Jersey) Incu-Shaker refrigerated/heated orbital shaker set to 200 rpm. A vial of water co-located with each sample set was used to monitor the temperature over the ~ 240-hour contact time. The resulting temperature fluctuations are shown in Figure 3.4 with error bars representative of the 2.2 °C measurement uncertainty of a Type K thermocouple. The weighted mean temperature for each set of batch contacts is provided in Table 3.4.

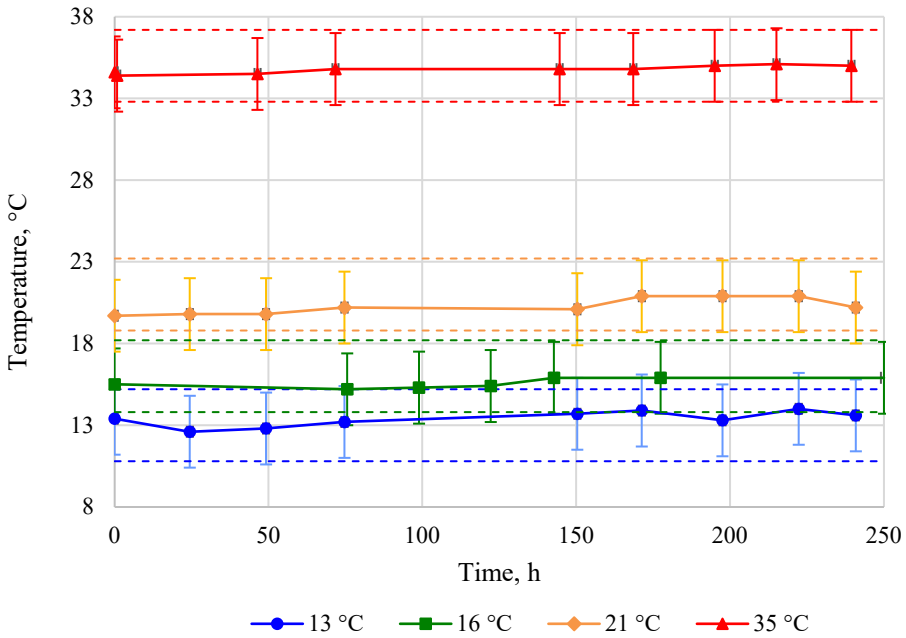


Figure 3.4. Temperature Profiles of Batch Contact Testing with SY-101 Tank Waste Supernate

Table 3.4. Average Contact Temperature

Target Temperature (°C)	Weighted Mean Temperature (°C)
13	13.4
16	15.6
21	20.3
35	34.8

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 gamma energy analysis (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. 2019a). 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).

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

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)

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

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)

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

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 Sample Analysis

Cesium load performance was determined from the ^{137}Cs measured in the collected samples relative to the native ^{137}Cs in the SY-101 feed. The collected samples were analyzed directly to determine the ^{137}Cs concentration using GEA. Cesium loading breakthrough curves for both the lead and lag 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 SY-101 feed was prepared by collecting a pro-rated volume from each feed bottle and combining in one glass scintillation vial; a composite effluent sample was similarly collected. Selected effluent samples from the lead and lag columns were measured for selected radionuclides and cations in an effort to assess the exchange behavior for these analytes. Table 3.5 summarizes the specific sample collections and targeted analytes along with the cross references to the sample identification numbers (IDs).

The feed and effluent samples were submitted to the ASO on ASR 1697. Select lead and lag column samples (also with duplicate feed and effluent composite samples) were submitted to Southwest Research Institute (SwRI). The respective analytical service provider was 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).

Table 3.5. Analytical Scope Supporting Column Processing

Sample ID	ASO/SwRI Sample ID	Analysis Scope
TI147-Comp-Feed	23-0589	GEA (^{60}Co, ^{137}Cs, ^{154}Eu) ICP-OES (Al, As, Ba, Ca, Cd, Cr, Fe, K, Na, Ni, P, Pb, S, Sr, Ti, U, Zn, Zr) Radioanalytical (^{90}Sr, ^{99}Tc, ^{237}Np, ^{238}Pu, $^{239+240}$Pu, ^{241}Am)
TI147-Comp-Eff	23-0590	GEA (^{60}Co, ^{137}Cs, ^{154}Eu) IC anions (F^-, Cl^-, NO_2^-, NO_3^-, PO_4^{3-}, $C_2O_4^{2-}$, SO_4^{2-}) Furnace oxidation (TOC, TIC) Acid titration (free OH) ICP-OES (Al, As, Ba, Ca, Cd, Cr, Fe, K, Na, Ni, P, Pb, S, Sr, Ti, U, Zn, Zr) ICP-MS (Ba, Nb, Pb, Sr, ^{238}U) Radioanalytical (^{90}Sr, ^{99}Tc, ^{237}Np, ^{238}Pu, $^{239+240}$Pu, ^{241}Am)
TI147-L-1	704601	ICP-AES ICP-MS (Cs) Radioanalytical (^{237}Np, ^{238}Pu, $^{239+240}$Pu,^{244}Pu, ^{241}Am, ^{242}Cm, ^{244}Cm)
TI147-L-3	704605	
TI147-L-5	704606	
TI147-L-7	704607	
TI147-L-9	704608	
TI147-L-11	704602	
TI147-L-13	704603	
TI147-L-15	704604	
TI147-P-1	704609	
TI147-P-3	704611	
TI147-P-5	704612	
TI147-P-7	704613	
TI147-P-9	704614	
TI147-P-11	704610	
TI147-L-16	705612	
TI147-L-18	705613	
TI147-L-20	705614	
TI147-L-22	705615	
TI147-L-24	705616	
TI147-L-26	705617	
TI147-P-14	705618	
TI147-P-16	705619	
TI147-P-18	705620	
TI147-P-20	705621	
TI147-Feed-Comp	705611	
TI147-EFF-Comp	705610	

ICP-OES = inductively coupled plasma optical emission spectroscopy
ICP-AES = inductively coupled plasma atomic emission spectroscopy
ICP-MS = inductively coupled plasma mass spectrometry
IC = ion chromatography
TIC = total inorganic carbon
TOC = total organic carbon

4.0 Results

This section discusses the Cs exchange behavior during batch contact and column testing with SY-101 tank waste. Batch contact raw data are provided in Appendix C. Ion exchange process raw data are provided in Appendix A.

4.1 Batch Contact Results

This section provides the K_d and isotherm curves for SY-101 tank waste at the four process test temperatures, and a comparison of SY-101 tank waste with AP-105, AP-107 and AP-101 temperature-dependent isotherm results. Input data supporting the various isotherms and figures are provided in Appendix C.

4.1.1 K_d and Isotherm Results for SY-101

Figure 4.1 shows the K_d dependence on Cs concentration at 13, 16, 25, and 35 °C with SY-101 tank waste. The K_d increased with decreasing temperature, consistent with AP-107 and AP-101 tank waste batch contact testing (Fiskum et al. 2021a). The K_d remains relatively consistent across the range of Cs concentrations measured bracketing the feed condition of 1.73 µg/mL Cs in SY-101 supernate.

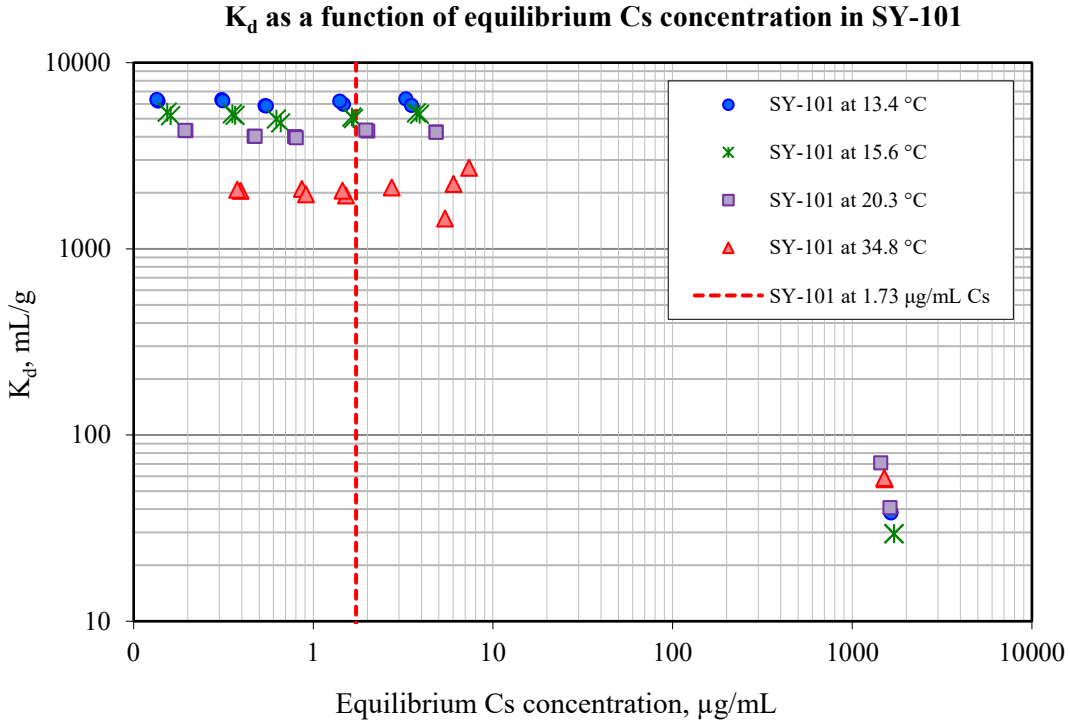


Figure 4.1. Cs K_d vs. Cs Concentration, SY-101 Tank Waste, Four Temperatures

Figure 4.2 shows the corresponding isotherms and Q (mmoles Cs/g dry CST) values vs. Cs molarity at all four test temperatures with SY-101 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. (4.2) (Hamm et al. 2002).

$$Q = \frac{\alpha_i \times [Cs]}{(\beta + [Cs])} \tag{4.1}$$

where

[Cs] = equilibrium Cs concentration, mmoles/mL or M
Q = equilibrium Cs loading on the CST, mmoles 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)

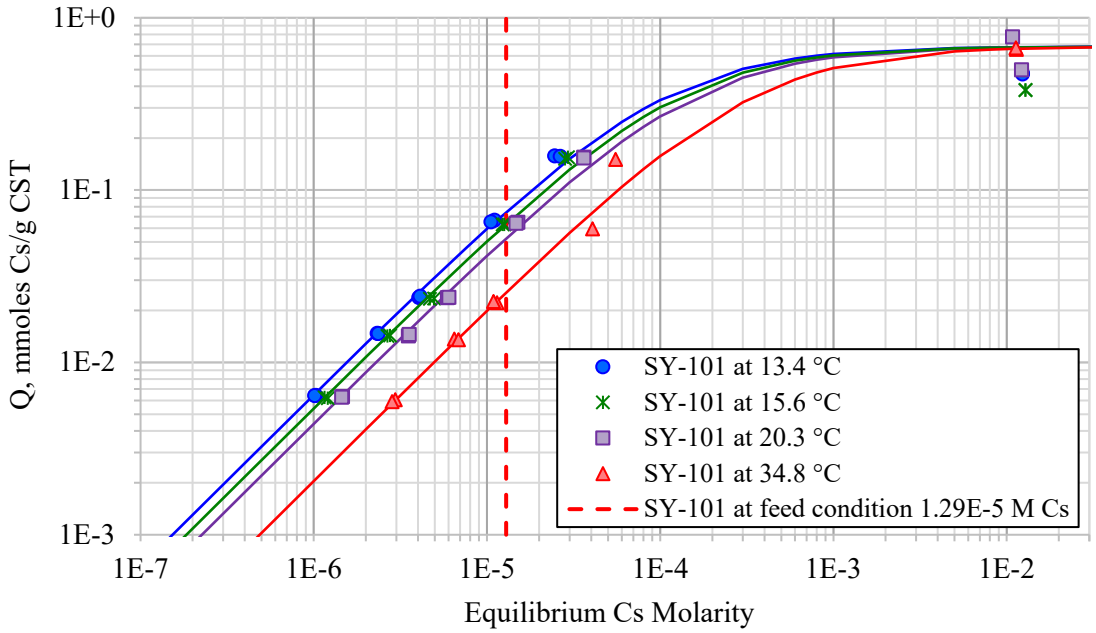


Figure 4.2. Q vs. Cs Equilibrium Concentration, SY-101 Tank Waste with Freundlich/Langmuir Hybrid Equilibrium Fits, Four Temperatures. The dashed red line represents the Cs concentration (1.29E-5 M) in SY-101 feed.

A plot of Q (mmoles Cs/g CST) vs. temperature (Figure 4.3) indicates that the loading decreases linearly as temperature increases. The slope of -0.0022 is the same slope obtained for temperature tests with simple simulant (1 M NaOH/4.6 M $NaNO_3$), AP-101 tank waste, and 7 M AP-105 tank waste.

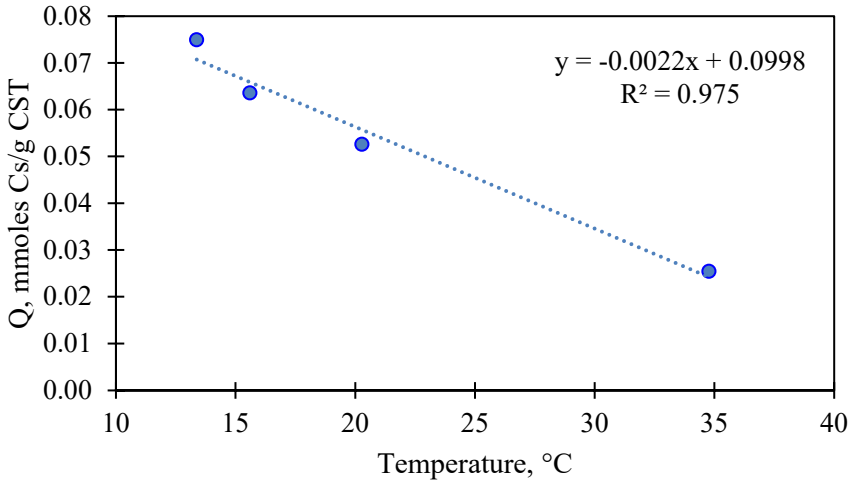


Figure 4.3. Q Dependence on Temperature for SY-101 Tank Waste

The experimental data for Cs loading (Q) at the five lowest Cs concentrations (3.4E-5, 7.5E-5, 1.2E-4, 3.4E-4, and 8.1E-4 M) bracketing Cs near the feed condition are better represented by a linear Freundlich isotherm fit as shown in Figure 4.4. A comparison of the loading calculated using the Freundlich/Langmuir hybrid model and the linear Freundlich approach is shown in Table 4.1. The loadings predicted by both isotherms are in excellent agreement at the SY-101 feed condition of 1.29E-5 M Cs.

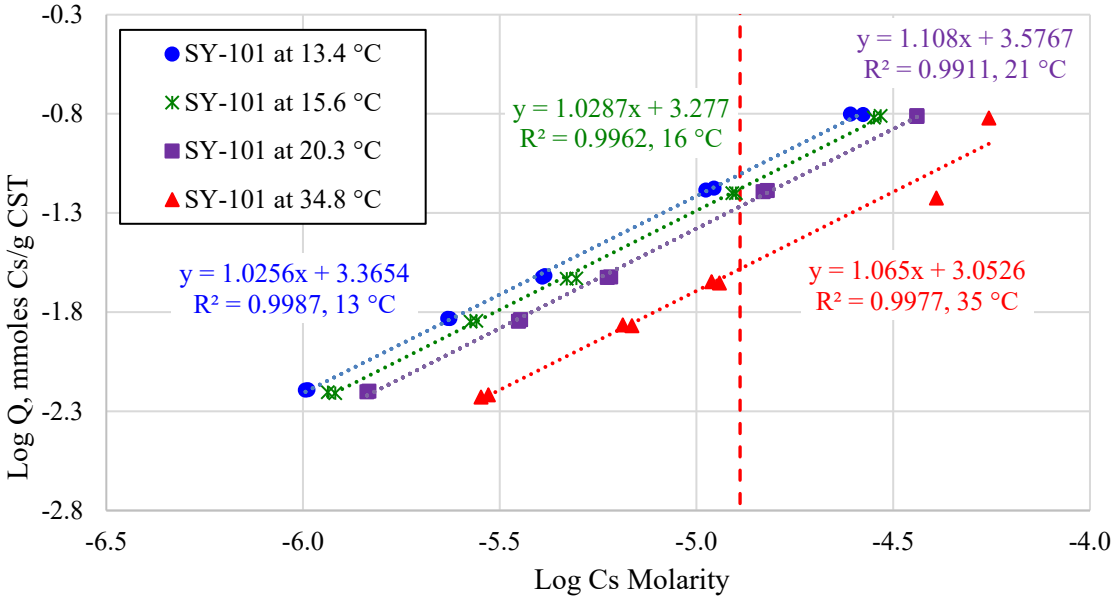


Figure 4.4. Linear Fits for Log Q vs. Log [Cs] at Four Test Temperatures where the dashed red line represents the SY-101 feed condition of 1.29E-5 M Cs.

Table 4.1. Cs loading (Q, mmoles Cs/g CST) for the Freundlich/Langmuir Hybrid and Linear Freundlich Isotherm Model at Feed Condition of 1.29E-5 M Cs

Process Temperature (°C)	Q (mmoles Cs/g) F/L Hybrid model	Q (mmoles Cs/g) Linear Freundlich model
13.4	0.075	0.079
15.6	0.064	0.066
20.3	0.053	0.054
34.8	0.026	0.026

4.1.2 Tank Waste Comparisons

The alpha parameter in the Freundlich/Langmuir hybrid model represents the maximum Cs loading that can be achieved under the corresponding matrix conditions. To compare the data across tank wastes, α_i (maximum Cs loading) was set to 0.68 mmoles Cs/g CST and Excel Solver was used to calculate the β parameters using a generalized reduced gradient nonlinear method. The calculated selectivity parameter, β, for SY-101, AP-107, AP-101, AP-105, and AP-105 (7 M Na) are shown in Table 4.2. The β parameter for SY-101 has the lowest delta (2.28E-4) across the temperature range studied when compared to the other tanks. Do recall SY-101 is located in the 200 West Area and may not portray the same behavior as the AP tanks in the 200 East Area. The β values linearly increased with temperature, which is expected as increasing temperature inhibits Cs loading. The smaller the β value, the more favorable the exchange. The β values for SY-101 were the smallest of the waste series measured, which likely can be traced back to the lower Na concentration.

Table 4.2. Freundlich/Langmuir Hybrid Equilibrium β Parameter Summary for SY-101, AP-107, AP-105, AP-101, and AP-105 (7 M Na) Tank Waste and Calculated Q and K_d

Matrix	Process Temperature (°C)	β, (Cs M)	K_d (mL/g)	Q (mmoles Cs/g CST)
SY-101 Tank Waste 1.29×10^{-5} M Cs	13.4	1.04E-4	5808	0.0749
	15.6	1.25E-4	4928	0.0636
	20.3	1.54E-4	4078	0.0526
	34.8	3.32E-4	1973	0.0255
AP-107 Tank Waste 6.91×10^{-5} M Cs	12.7	3.49E-4	1497	0.103
	15.9	4.43E-4	1249	0.086
	21.0	5.03E-4	1138	0.079
	34.5	9.74E-4	681	0.047
AP-101 Tank Waste 4.64×10^{-5} M Cs	12.9	3.85E-4	1721	0.0799
	15.7	4.76E-4	1391	0.0645
	21.7	5.28E-4	1237	0.0574
	34.3	9.29E-4	666	0.0309
AP-105 Tank Waste 5.65×10^{-5} M Cs	12.7	4.91E-4	1242	0.070
	15.9	6.11E-4	1019	0.058
	21.0	6.54E-4	956	0.054
	34.5	1.28E-3	510	0.029
AP-105 Tank Waste (7 M Na) 7.19×10^{-5} M Cs	13.1	5.18E-4	1153	0.0829
	15.3	5.46E-4	1101	0.0792
	24.9	8.88E-4	708	0.0509
	35.2	1.31E-3	491	0.0353

Figure 4.5 compares the K_d values vs. temperature for SY-101, AP-107, AP-105 (5.5 and 7 M Na), and AP-101 tank waste. The K_d values from SY-101 are nearly 4x those measured for AP farm tanks. Interestingly, as the temperature increases, the difference in the K_d between SY-101 and the AP tanks decreases. The K_d values are calculated from the Freundlich/Langmuir fit of the experimental data from the waste series with α_i = 0.68 mmoles Cs/g CST. This does use the initial Cs concentration from the tank waste supernate, which followed the order SY-101<AP-101<AP-105 (FY20) < AP-105 (FY23) < AP-107, where SY-101 had the lowest Cs concentration; and consequently, the highest K_d.

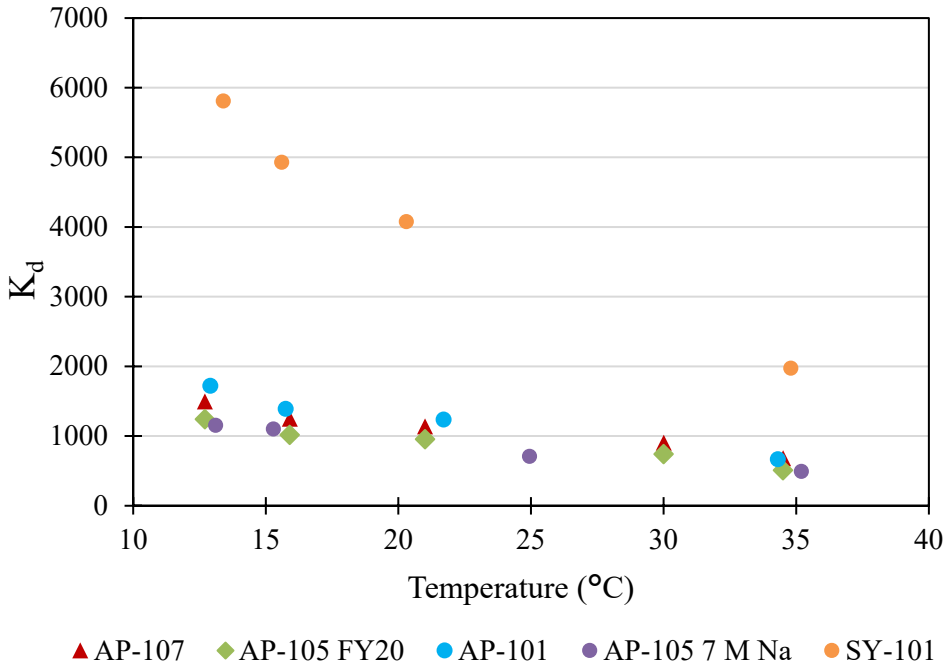


Figure 4.5. Cs K_d vs. Temperature for SY-101, AP-105 (5.5 and 7 M Na), AP-107, and AP-101 Tank Waste at Corresponding Feed Conditions

4.2 Ion Exchange Processing

The Cs load behavior for SY-101 tank waste was evaluated at 16 °C in a lead-lag column format. This section discusses the Cs exchange behavior during the load, FD, water rinse, and final solution flush from the column system.

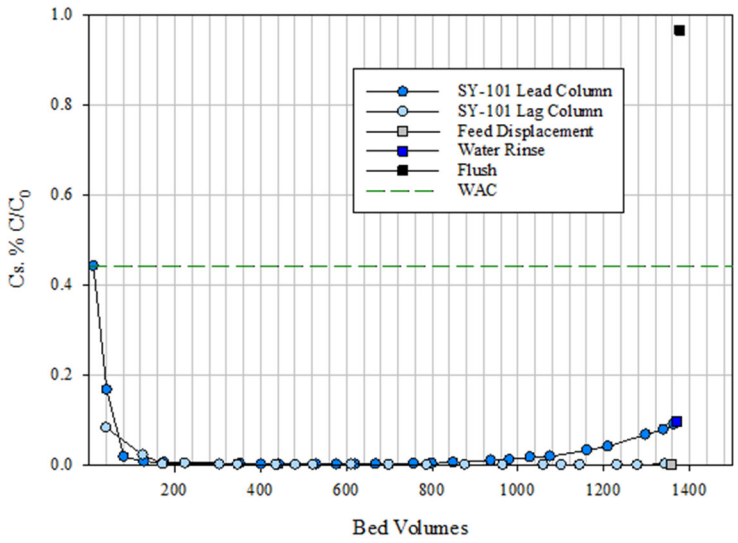
4.2.1 Cs Loading for SY-101, Feed Displacement, and Water Rinse

The SY-101 feed was processed continually at nominally 1.87 BV/h through the lead and lag columns for 1345 BVs. Due to the lack of Cs breakthrough established during testing, a polish column was not needed. Figure 4.6a shows a linear-linear plot of the cesium load profile for feed processed through each column. The x-axis shows the BVs processed and the y-axis shows the effluent Cs concentration (C) relative to the feed concentration (C_0) in terms of % C/C_0. The C_0 value for ^{137}Cs was determined to be 20.6 µCi/mL (average of all filtered feeds, relative standard deviation of 5.0%). In this graph, the Cs breakthrough from the lead column appeared to start at ~1000 BVs and continued to 0.1% C/C_0 after processing 1345 BVs when the last sample was collected from the lead column. The lag column Cs breakthrough performance is not discernable at this linear scale. Note, the high Cs concentrations in the

initial lead column samples were a result of residual contamination from the previous manifold use with 7 M Na AP-105 (Westesen et al. 2023).

Figure 4.6b shows the same Cs load data provided in Figure 4.6a but with the ordinate % C/C_0 on a probability scale and the abscissa BVs processed on a log scale. Under normal load processing conditions, these scales provide a predictable straight-line Cs breakthrough curve and provide greater fidelity of load characteristics at low and high % C/C_0 values (Buckingham 1967). In contrast to Figure 4.6a, the Cs breakthrough from the lead column was observed to occur at around 600 BVs. There is no discernable breakthrough from the lag column. In addition to the 50% C/C_0 indication line, the WAC limit, set at 0.44% C/C_0, is also apparent (dashed green line).[6] There was not enough volume of SY-101 to reach the WAC limit on the lead column, but this point can be extrapolated from the given breakthrough data and calculated to be around 1664 BVs.

a)



[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: 3.18×10^{-5} Ci ^{137}Cs/mole Na. At 2.85 M Na and 20.6 µCi ^{137}Cs/mL in the feed, the WAC limit translates to 0.440% C/C_0.

b)

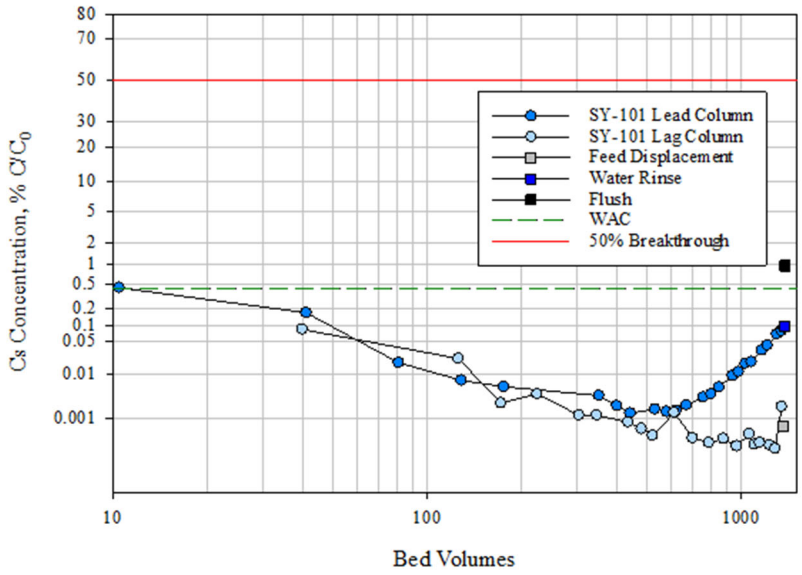


Figure 4.6. Lead and Lag Column Cs Load Profiles of SY-101 at 1.90 BV/h: a) Linear-Linear Plot; b) Probability-Log Plot

The Cs breakthrough curves were modeled by the error function (erf) (Hougen and Marshall 1947; Klinkenberg 1948), as shown in Eq. (4.2):

$$\frac{C}{C_0} = \frac{1}{2}\left(1 + \text{erf}\left(\sqrt{k_1 t} - \sqrt{k_2 z}\right)\right) \tag{4.2}$$

where:

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

Using this model, a fit was generated to the lead column experimental data (see Figure 4.7). It is important to note, this extrapolation is based on experimental breakthrough behavior through 1% and has a large error associated with extrapolating out to the 50% breakthrough point. The lag column was not analyzed due to lack of substantial breakthrough behavior. The 50% Cs breakthrough for the SY-101 lead column was estimated from the error function fit at 4944 BVs.

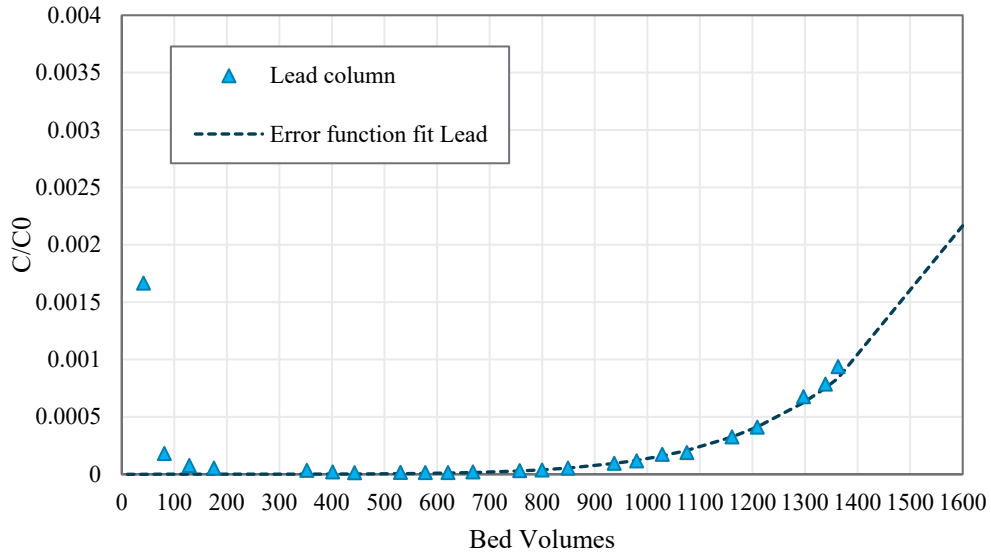


Figure 4.7. SY-101 Lead Column Cs Breakthrough with Error Function Fit

The theoretical 50% Cs breakthrough on the ion exchange column (λ) can be predicted from the product of the K_d value and the ion exchanger bed density (ρ_b) according to Eq. (4.3) (Bray et al. 1993). The CST bed density is the dry CST mass divided by the volume in the column:

$$K_d \times \rho_b = \lambda \quad (4.3)$$

Despite the large extrapolation from the lead column experimental data, the 50% Cs breakthrough value had excellent agreement (within 1%) to the Cs λ value predicted from the 16 °C batch contact studies (4928 BVs).

The WAC limit Cs breakthrough was also extrapolated for the lead column by curve-fitting the BVs processed as a function of the log % C/C_0 values (see Figure 4.8). The curve was fitted to a second-order polynomial function ($R^2 \geq 0.99$) and the WAC limit breakthrough was then calculated, resulting in an estimated value of 1664 BVs.

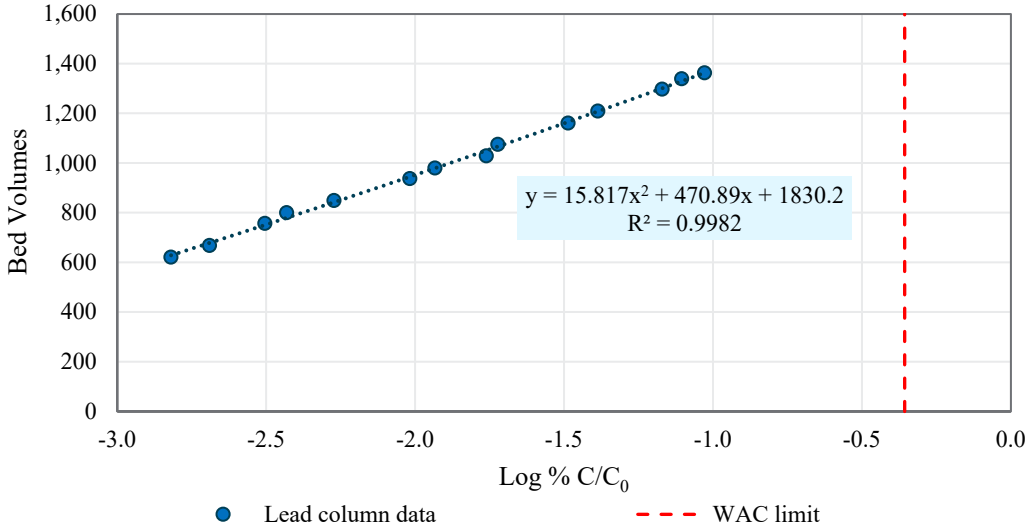


Figure 4.8. Curve Fit to Extrapolate WAC Limit Breakthroughs from SY-101 Lead Column

Figure 4.9 shows the end of the Cs breakthrough profile from the lead and lag columns with the FD, water rinse, and the final flushed fluid from the column system on a probability-linear plot. The linear abscissa scale provides better Cs concentration resolution of the various effluent solutions relative to graphing on a log scale. After the 12 BVs (1.6 AVs) of 0.1 M NaOH FD, the Cs concentration dropped from 1.89E-03 % C/C_0 at the end of the last lag column sample to 6.14E-4 % C/C_0, consistent with the displacement of residual feed from the system. Surprisingly, the ensuing water rinse did not result in a continued downward trajectory in the Cs concentration; in fact, an increase to 9.7E-2 % C/C_0 was observed. As observed previously (Fiskum et al. 2021b; Fiskum et al. 2019b; Rovira et al. 2019), the Cs concentration in the solution expelled with compressed air bumped the Cs concentration up past the WAC limit. No effort was made to filter this solution prior to ^{137}Cs analysis, so it is not clear if this increased Cs concentration was associated with suspended fines or if a small amount of Cs had exchanged back into solution during the contact period with the water rinse.

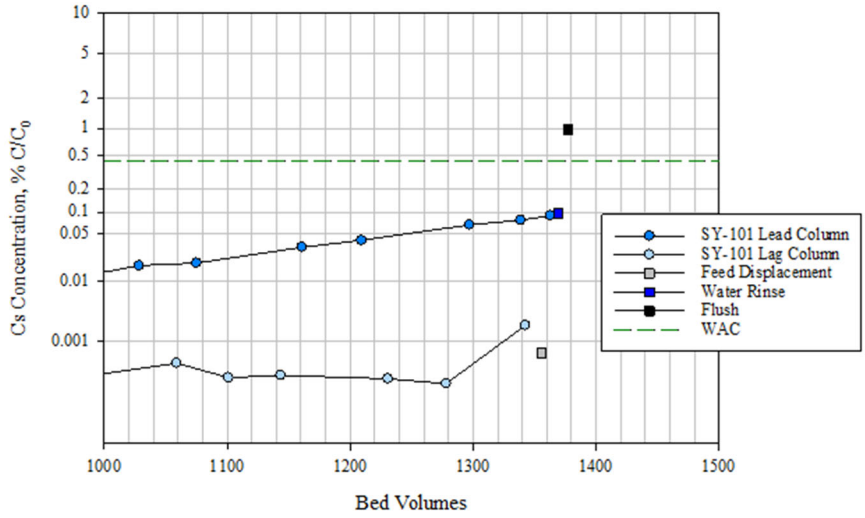


Figure 4.9. SY-101 Column Cs Load Profiles with Feed Displacement, Water Rinse, and Column Flush Solution

4.2.2 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 and lag columns were determined by subtracting the Cs recovered in the samples and effluents from the Cs fed to each column. Table 4.3 summarizes the ^{137}Cs fractions found in the various effluents as well as the calculated ^{137}Cs column loadings. Approximately 94 % of the total Cs loaded onto the lead column and 6% loaded onto the lag column. Sample and effluent collection amounted to only ~0.06% of the input Cs.

Table 4.3. ^{137}Cs Activity Balance for SY-101

Input		
	µCi	%
Feed sample	1.69E+05	100
Output		
Effluent-1 (0-226 BVs)	19.387	1.14E-02
Effluent-2 (226-440 BVs)	0.306	1.81E-04
Effluent-3 (440-663 BVs)	0.061	3.58E-05
Effluent-4 (663-884 BVs)	0.021	1.25E-05
Effluent-5 (884-1111 BVs)	0.018	1.08E-05
Effluent-6 (1111-1330 BVs)	0.026	1.54E-05
Effluent-7 (1330-1355 BVs)	0.308	1.82E-04
Load samples	72	0.04
Feed displacement, water rinse and flush	11.3	0.007
Total ^{137}Cs recovered in effluents	103.2	0.06
Total ^{137}Cs column loading		
Lead column Cs loading	1.59E+05	93.6
Lag column Cs loading	1.07E+04	6.3
Column total	1.69E+05	100.0

The total Cs loaded per g CST (effective capacity) was calculated from the total ^{137}Cs predicted to be loaded onto the column, at 50% Cs breakthrough, and the dry CST mass was loaded into the lead column. The Cs mass loaded onto the CST bed was calculated according to Eq. (4.4):

$$\frac{A_{Cs} \times CF}{M} = C \tag{4.4}$$

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

Table 4.4 summarizes the CST Cs loading performance for the column test. Batch contact testing resulted in a measured Cs loading of 0.0636 mmoles Cs/g CST at 1.73 µg/mL Cs equilibrium. In agreement with the compared K_d values, the predicted column loading value for SY-101 was within 1% of the Cs loading values predicted from the 16 °C batch contact studies. This Cs loading is nearly 20% higher than loading seen for 16 °C processing with east area supernate wastes (Westesen et al. 2023, Westesen et al. 2022, Westesen et al. 2021b). This is likely a direct result of the lower Na and Cs concentration in the SY-101 supernate.

Table 4.4. CST Cs Load Performance Summary in the SY-101 Column Test

BV Processed	Flowrate (BV/h)	Initial Cs Concentration (µg Cs/mL)	Cs Loading (mg Cs/g CST)(*)	Cs Loading (mmoles Cs/g CST) (*)
1334	1.87	1.73	8.54	0.0638

(*) This value is predicted based on the extrapolated 50% breakthrough value

4.2.3 Metals and Radionuclide Analysis

The SY-101 composite feed and composite effluent samples underwent extensive characterization to better define waste characteristics and assess analyte fractionation to the CST. Additionally, 14 lead column samples and 10 lag column samples were also selected for metals and radionuclide analysis to assess analyte load characteristics. Table 4.5 shows the BVs processed associated with each selected sample.

Table 4.5. Selected Lead and Lag Column Bed Volumes (BVs) Processed

Lead Column Sample ID	BVs Processed	Lag Column Sample ID	BVs Processed
TI147-L-1	10.5	TI147-P-1	40.0
TI147-L-3	81.1	TI147-P-3	171.6
TI147-L-5	175.2	TI147-P-5	304.0
TI147-L-7	270.5	TI147-P-7	435.6
TI147-L-9	401.2	TI147-P-9	522.1
TI147-L-11	530.1	TI147-P-11	698.4
TI147-L-13	620.6	TI147-P-14	964.8
TI147-L-15	756.9	TI147-P-16	1100.9
TI147-L-16	799.7	TI147-P-18	1230.8
TI147-L-18	936.8	TI147-P-20	1342.4
TI147-L-20	1028.3		
TI147-L-22	1160.8		
TI147-L-24	1297.1		
TI147-L-26	1362.7		

Table 4.6 and Table 4.7 summarize the feed and effluent radionuclide and metals concentrations and their respective fractionations to the effluent. The anions and free hydroxide concentrations in the effluent are provided in Table 4.8; they were not measured in the feed because it was shown that their concentrations were not affected by the CST processing (Westesen et al. 2021a). Further, bench handling of the effluent was safer for the analysts from a radiological dose perspective. 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 and the total analyte collected in the Cs-decontaminated effluent according to Eq. (4.5):

$$\frac{C_{Da} \times V_D}{C_{Fa} \times V_F} = F_{Da} \tag{4.5}$$

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 SY-101 feed
V_F = volume of SY-101 feed
F_{Da} = fraction of analyte *a* in the Cs-decontaminated effluent

The analyte results shown in brackets indicate 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. The opportunistic analyte results measured by ICP-OES are also shown in Table 4.7; these analytes are part of the ICP-OES data output but have not been fully evaluated for quality control performance.

Table 4.6. SY-101 Feed & Effluent Radionuclide Concentrations and Fractionations

Analysis Method	Analyte	Feed Conc. TI147-Comp-Feed (µCi/mL)	Effluent Conc. TI147-Comp-Eff (µCi/mL)	Fraction in Effluent (%)
Gamma energy analysis (GEA)[(a)]	^{60}Co	<1.5E-4	2.69E-04	--
	^{126}Sn	<5.2E-3	9.85E-04	--
	^{126}Sb	<1.4E-3	8.38E-04	--
	^{137}Cs	9.10E+01	2.41E-02	0.026%
	^{154}Eu	<1.2E-3	<7.5E-6	--
Separations/ Alpha energy analysis (AEA)[(a)]	^{237}Np	2.22E-06	1.49E-07	6.7%
	^{238}Pu	2.49E-05	4.33E-06	17.4%
	$^{239+240}$Pu	1.41E-04	2.56E-05	18.1%
	^{241}Am	1.32E-04	2.37E-06	1.8%

(a) Reference date is May 2023.
"--" = 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 4.7. SY-101 Feed and Effluent Inorganic Analyte Concentrations and Fractionation (ASR 1697)

Analysis Method	Analyte	Feed Concentration (M)	Effluent Concentration (M)	Fraction in Effluent
ICP-OES	Al	1.27E-01	1.30E-01	101%
	Ca	[1.4E-04]	[2.8E-04]	198%
	Cr	2.11E-03	2.05E-03	96%
	Cu	[3.1E-05]	[3.3E-05]	107%
	K	1.28E-02	7.92E-03	61%
	Na	2.82E+00	2.74E+00	96%
	Mo	1.16E-04	1.34E-04	113%
	P	[8.3E-02]	8.07E-02	96%
	S	2.74E-02	2.64E-02	95%
	Analyte	Feed Concentration (M)	Effluent Concentration (µg/g)	Analyte mass in effluent (µg)
ICP-MS	Ba	--	<7.71E-2	--
	Nb	--	1.79E-01	1.7
	Pb	--	9.02E+01	8.6
	Sr	--	<5.78E-2	--
	^{238}U	--	2.01E+00	19.2

Notes:
Values in brackets [ ] were ≥ MDL but < EQL, with errors likely to exceed 15%.
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 4.8. SY-101 Feed and Effluent Anions and Carbon Composition (ASR 1697)

Analysis Method	Analyte	Feed Concentration (M)	Effluent Concentration (M)
Titration	Free Hydroxide	NA	1.23
Ion Chromatography	F^-	NA	1.57E-03
	Cl^-	NA	9.90E-02
	NO_2^-	NA	9.74E-01
	NO_3^-	NA	1.88E+00
	PO_4^{3-}	NA	8.23E-03
	$C_2O_4^{2-}$	NA	8.69E-05
	SO_4^{2-}	NA	2.46E-02
Hot persulfate oxidation	Total organic C	3.81E-01	3.96E-01
	Total inorganic C[(a)]	1.40E-01	1.42E-01
	Carbonate	3.14E-01	2.83E-01
NA= not analyzed			

The ICP-OES results for the feed composite and effluent composite showed that the majority of analytes remained in the effluent (see Table 4.7 and Appendix B for analytical reports). The Al, Cr, Cu, Na, and S (sulfate) partitioned exclusively to the effluent (>5% recovery) in the SY-101. Potassium (K) showed an

under recovery in the effluent with nominally 40% sorbing to the CST. A significant fraction (>80%) of the radionuclides sorbed to the CST. This is in contrast to previous testing from east area DSTs those showed nominally 75-80% of the ^{237}Np, ^{238}Pu, $^{239+240}$Pu, and ^{241}Am partitioned to the effluent. This uptake of TRU radionuclides resulted in 184 nCi/g loaded onto all 12 grams of the CST (exceeding the TRU threshold of 100 nCi/g) and if all analytes loaded only onto the lead column would result in 368 nCi/g.

Selected lead and lag column effluent samples were also analyzed for ^{237}Np, ^{238}Pu, $^{239+240}$Pu, and ^{241}Am. Figure 4.10 compares their load profiles for the lead column and Figure 4.11 compares the profiles of the lag column. A somewhat sporadic but significant breakthrough was exhibited by ^{237}Np throughout processing on both the lead and lag column samples. In both cases, a ~40% breakthrough was consistently observed, indicating a fraction of the Np was not able to be removed by the CST and passively moved through the system. Similarly, ^{238}Pu and $^{239+240}$Pu breakthrough demonstrated nominally 80% 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. Nearly full removal of ^{241}Am was observed, with only 1% breakthrough seen consistently in the effluent samples.

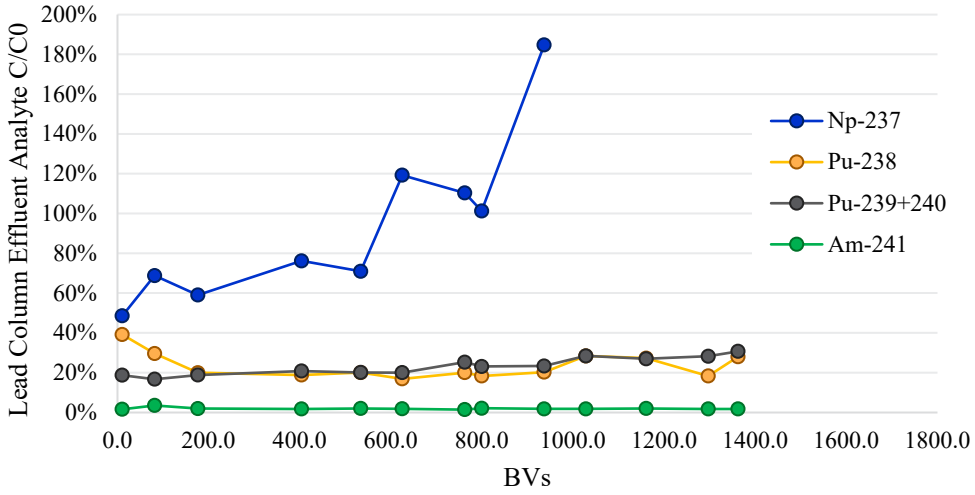


Figure 4.10. ^{237}Np, ^{238}Pu, $^{239+240}$Pu, and ^{241}Am Load Profiles from the Lead Column

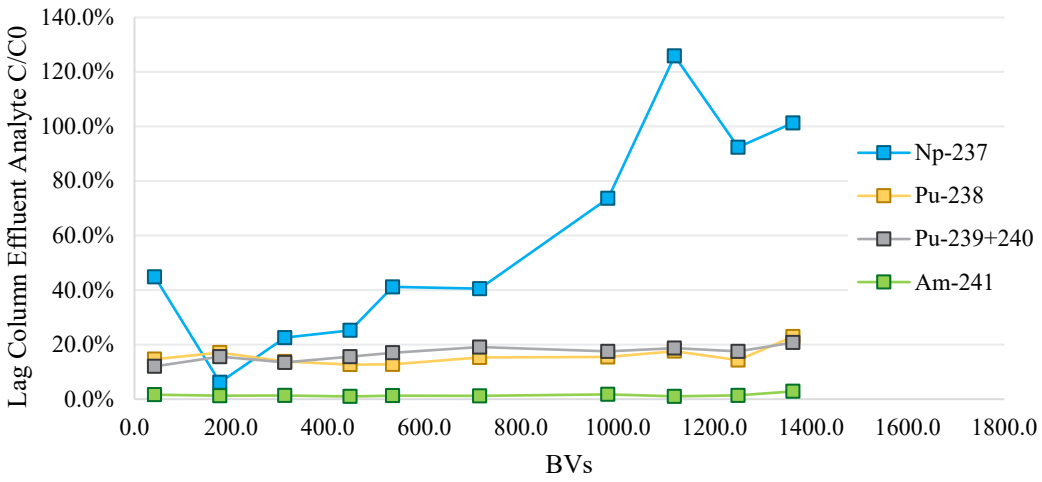


Figure 4.11. ^{237}Np, ^{238}Pu, $^{239+240}$Pu, and ^{241}Am Load Profiles from the Lag Column

5.0 Conclusions

Cesium ion exchange column and batch contact testing was conducted with CST lot number 2002009604 sieved to <30 mesh to assess Cs ion exchange performance with SY-101 tank waste.. Column testing was conducted at a small scale in PNNL's Radiochemical Processing Laboratory hot cells to accommodate the high radiological dose rate of the Hanford tank waste matrix. The results are summarized below.

5.1 Column Testing

SY-101 tank waste was processed through a two-column format. A total of 8.2 L of SY-101 tank waste was processed through the Cs ion exchange system at 1.90 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 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 1362 BVs of SY-101 tank waste, processed at 1.90 BV/h at 16 °C, can be treated before reaching the WAC on the lead column.
2. The total predicted Cs loading onto the lead column at the 50% breakthrough (8.54 mg Cs/g CST) was nominally 20% higher than loadings seen for 5-7 M Na supernates from the 200 east area. This is a direct correlation with the lower Na (2.8 M) and Cs concentrations in the SY-101 supernate.

5.1.1 Analyte Fractionation

1. Major components Al, Cr, Cu, Na, and S (sulfate) partitioned exclusively to the effluent. Recoveries of K showed nominally ~40% was removed by the CST.
2. The effluent contained less than 10% of the feed Np, 18% of the feed Pu, and 2% of the feed Am. The balances of these isotopes were assumed to remain on the CST. Assuming the retained isotopes were bound only to the lead column CST bed, the CST would contain 368 nCi/g TRU, which is significantly above the 100 nCi/g threshold defining TRU waste.
3. Select lead and lag column samples showed a significant ^{237}Np breakthrough over the volume of waste processed. Nearly all the ^{241}Am was removed by the CST, however, ~40% of the Np and 20% of the Pu appeared to be in a form that was not able to be removed by the CST.

5.2 Batch Contact Testing

Cesium isotherms were developed for SY-101 tank waste at 13.4, 15.6, 20.3, and 34.8 °C using decontaminated effluent post ion exchange processing with nonradioactive Cs concentrations of 3.3E-5, 7.5E-5, 1.2E-4, 3.4E-4, 8.1E-4 M, and 1.5E-2 M. Batch contacts were conducted in duplicate with 0.075 g dry CST (lot number 2002009604) per 15 mL of solution and agitated in a temperature-controlled box for ~240 hours. The isotherm data were fit to the Freundlich/Langmuir hybrid equilibrium model and the linear Freundlich model (for the lowest four Cs concentrations) to calculate K_d and Q values at SY-101 feed condition of 1.29E-5 M. Results of SY-101 batch contact testing were compared to AP-107, AP-105 (5.5 and 7 M Na), and AP-101 temperature studies. The following conclusions were made from this testing:

1. The Freundlich/Langmuir hybrid model accurately predicts the loading near the SY-101 feed condition. The linear Freundlich isotherm predicts loading with $R^2 > 0.99$ for the four lowest Cs concentrations at all temperatures.
2. The β values are smallest for SY-101 when compared to AP-105, AP-107 and AP-101, meaning the matrix is significantly more favorable for Cs uptake than the 200 east area tanks and can likely be traced back to the notably lower Na concentration.

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Appendix A – SY-101 Column Load Data

The SY-101 lead and lag column loading raw data are provided in Table A.1. The raw 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 and Lag Column Cs Breakthrough Results with SY-101

Lead Column				Lag Column			
BV	µCi ^{137}Cs/ mL	% C/C_0	DF	BV	µCi ^{137}Cs/ mL	% C/C_0	DF
10.48	9.11E-2	4.42E-1	226	40.0	1.71E-2	8.30E-2	1,205
41.2	3.43E-2	1.67E-1	600	125.6	4.58E-3	2.22E-2	4,501
81.1	3.74E-3	1.81E-2	5,517	171.6	4.69E-4	2.28E-3	43,908
128.4	1.57E-3	7.60E-3	13,159	223.7	7.66E-4	3.72E-3	26,918
175.2	1.12E-3	5.45E-3	18,349	304.0	2.41E-4	1.17E-3	85,426
228.0	2.03E+1	9.86E+1	1	346.4	2.44E-4	1.18E-3	84,495
270.5	2.08E+1	1.01E+2	1	435.6	1.62E-4	7.86E-4	127,238
352.0	7.10E-4	3.44E-3	29,044	480.8	1.12E-4	5.45E-4	183,338
401.2	4.10E-4	1.99E-3	50,220	522.1	7.50E-5	3.64E-4	274,923
442.8	2.71E-4	1.32E-3	76,027	611.0	2.81E-4	1.36E-3	73,404
530.1	3.37E-4	1.64E-3	61,131	698.4	6.46E-5	3.14E-4	318,921
577.5	2.93E-4	1.42E-3	70,320	787.5	4.87E-5	2.36E-4	423,345
620.6	3.12E-4	1.52E-3	65,985	876.4	6.19E-5	3.00E-4	332,989
668.1	4.21E-4	2.04E-3	48,989	964.8	3.99E-5	1.94E-4	516,675
756.9	6.45E-4	3.13E-3	31,931	1058.7	8.25E-5	4.00E-4	249,870
799.7	7.64E-4	3.71E-3	26,979	1100.9	4.42E-5	2.14E-4	466,472
849.0	1.10E-3	5.34E-3	18,722	1143.6	4.89E-5	2.37E-4	421,308
936.8	1.98E-3	9.60E-3	10,416	1230.8	4.18E-5	2.03E-4	493,084
979.5	2.40E-3	1.17E-2	8,577	1278.0	3.40E-5	1.65E-4	606,701
1028.3	3.58E-3	1.74E-2	5,763	1342.4	3.90E-4	1.89E-3	52,794
1075.1	3.91E-3	1.90E-2	5,277				
1160.8	6.73E-3	3.26E-2	3,063				
1209.2	8.47E-3	4.11E-2	2,434				
1297.1	1.39E-2	6.75E-2	1,480				
1338.8	1.62E-2	7.86E-2	1,273				
1362.7	1.93E-2	0.09	1,066				

BV = bed volume, 6 mL/BV
DF = decontamination factor
C_0 = 21 µCi ^{137}Cs/ mL (reference date March 2023)

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 Service Request (ASR) number. Cross-references of ASO sample IDs to test description are provided in the body of the report (see of the main report).

Appendix B Table of Contents

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: _____81126_____
Work Package: _____NP1205_____

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: _____ ASR 1386.00_____
  or, Previous RPL Number: _____

Does the Waste Designation Documentation Indicate Presence of PCBs?
X 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: ___1673____Rev.: __00____
RPL Numbers: ___(23-0329) to (23-0331)_____
(first and last)

ASO Work Accepted By: _____ **Signature/Date:** _____

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

ASO Staff Use Only				ASO Staff Use Only	
RPL Number	**Customer Sample ID**	**Sample Description (& Matrix, if it varies)**	**Analysis Requested**	**Test**	**Library**
23-0329	1SY-23-COMP-Cs	Cs component from SY-101 tank waste in 0.45 M HNO_3	ICP-MS mass fractionation of Cs (^{133}Cs, ^{135}Cs, ^{137}Cs)		
23-0330	1SY-23-COMP -GEA	0.1 mL SY-101 tank waste in 1.9 mL 0.1 M NaOH	GEA for ^{137}Cs, ^{241}Am, ^{60}Co		
23-0331	1SY-23-COMP	SY-101 tank waste supernate	Acid Digestion-128 • ICP-OES: Al, K, and Na		
	1SY-23-COMP-Cs-#2	Cs component from SY-101 tank waste in 0.45 M HNO_3	ICP-MS mass fractionation of Cs (^{133}Cs, ^{135}Cs, ^{137}Cs)		

ASR # ____1673_____Rev.: _00___

Gamma Energy Analysis (GEA)

Project / WP#:	81126/NP1205
ASR#:	1673
Client:	A. Westesen
Total # of Samples:	1

RPL ID	Client Sample ID
23-0330	1SY-23-COMP -GEA

Analysis Type:	GEA
Sample Processing Prior to Radiochemical Processing/Analysis	☒ None ☐ Digested as per RPG-CMC-128, Rev.1, *HNO_3-HCL Acid extraction of Liquids for Metals Analysis Using a Dry-Block Heater* ☐ Fusion as per RPG-CMC-115, *Solubilization of Metals from Solids Using a KOH-KNO_3 Fusion*
Pre-dilution Prior to Radiochemical Processing?	☒ No ☐ Yes
Analysis Procedure:	Activity #4468 – *Gamma Energy Analysis (GEA)*
Reference Date:	02/22/2023 @ 9:00 am
Analysis Date or Date Range:	2/22/2023 for GEA
Technician/Analyst:	TL Trang-Le and LR Greenwood for GEA
Rad Chem Electronic Data File:	RPG-RC\PNL\Projects\Backup files\Backup 23\23-0330 Westesen(SY-101).xlsx
ASO Project 98620 File:	File Plan 5872: T4.4 Technical (Radiochemistry), Gamma Calibration, daily checks, and maintenance records; and T3 standard certificates and preparation. ERecords CASE1830.150173A
M&TE Number(s):	Detector G for GEA

_____ / _____ _____ / _____

Preparer **Date** **Reviewer** **Date**

_____ / _____

QE Review **Date**

SAMPLE RESULTS

Activities for all gamma emitters detected in these samples are presented in an attached Excel spreadsheet for ASR 1673.00. All sample results for target isotopes are reported in units of µCi/sample with estimates of the total propagated uncertainty reported at the 1-sigma level.

ASO Project File, ASR 1673 has been created for this report including all appropriate supporting records which includes the Pipette Performance Check Worksheet forms, laboratory bench records, and Liquid Scintillation Counter Analysis printouts. All supporting records are available upon request. Standard certificates, detector calibration records, control charts and balance calibration records can be found in the ASO Records.

Sample preparation and counting

One sample with 2mL sent for gamma on February 22, 2023.

QUALITY CONTROL RESULTS

Tracer:

Tracers are not used for ASO GEA methods.

Process Blank (PB):

No process blank was prepared by ASO for gamma counting.

Required Detection Limits

There are no required detection limits for these samples.

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

There are no BS, LCS or MS samples analyzed for ASO GEA analyses. Instrument performance is assessed by the analyses of daily control counts and weekly background counts, as discussed below.

Duplicate Relative Percent Difference (RPD):

No duplicate samples were provided for gamma counting.

Instrument Calibration and Quality Control

Gamma detectors are calibrated using multi-isotope standards that are NIST-traceable and prepared in the identical counting geometry to all samples and detectors. Counter control sources containing Am-241, Cs-137 and Co-60 are analyzed daily before the use of each detector. Lab Assist Activity 4468, Gamma Energy Analysis, requires that a counter control source is checked daily and must be within ±3 sigma or ±3% of the control value, whichever is greater. Gamma counting was not performed unless the control counts were within the required limits. Background counts are performed on all gamma detectors at least weekly for either an overnight or weekend count.

Assumptions and Limitations of the Data

None

Interferences/Resolution

None

Uncertainty

For gamma counting, the uncertainty in the counting data, photon abundance and the nuclear half-life, and efficiency are included in the calculation of the total uncertainty along with a systematic uncertainty for sample prep. The Canberra Genie software includes both random and systematic uncertainties in the calculation of the total uncertainties which are listed on the report. We conservatively estimate that 2% is the lowest uncertainty possible for our GEA measurements considering systematic uncertainties in gamma calibration standards.

Comments

None

Attachment: Data Report Sample Results for ASR 1673.00.

Pacific Northwest National Laboratory
PO Box 999, Richland, WA
Radiochemical Sciences and Engineering Group

filename 23-0330 Westesen (SY101)
2/22/2023

Client: A. Westesen
ASR 1673

Project: 81126
WP#: NP1205

Prepared by: _____

Technical Reviewer: _____

Procedures: Activity #4468- Gamma Energy Analysis (GEA) and Low-Energy Photon Spectrometry (LEPS)

M&TE: Gamma detectors G
Count dates: 22-Feb-23

Measured Activity, µCi/sample ± 1s

RPL ID:	23-0330	
Sample ID:	**1SY-23-COMP-GEA**	
Isotope		
Co-60	<5.11E-5	
Cs-137	**2.03E+00**	**± 2%**
Am-241	<2.24E-3	

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

Project / WP#: **81126** / NP1205 **ASR#:** 1753
Client Name: **A. Westesen** **Total Samples:** **1** (liquid)
Client Sample Description: Cs component from SY-101 tank waste in 0.45 M HNO3.

ASO Sample ID	**Client Sample ID**
23-0924	1SY-23-COMP-Cs #2

Sample Preparation: Simple dilution of samples in 2% v/v HNO_3 was performed by C. Perez on 5/22/2023.

Procedure: RPG-CMC-292, Rev. 1, "Determination of Elemental Composition by Inductively Coupled Argon Plasma Mass Spectrometry (ICP-MS)."

Analyst(s):	C. Perez	**Analysis Date:**	5/23/2023	**ICP File:**	M0333

See Chemical Measurement Center 98620 file: ICP-MS-325-405-1 (Calibration and Maintenance Records)

M&TE:			
☒	PerkinElmer NexION™ 350X ICP-MS	SN: 85VN4070702	RPL 405
☒	Ohaus PA224C Balance	SN: B725287790	RPL 405
☐	Mettler AT400 Balance	SN: M19445	RPL 405 FH
☐	Mettler AT400 Balance	SN: 1113162654	RPL 420 FH
☐	Mettler AT400 Balance	SN: 1113292667	RPL 420 FH
☐	Sartorius R200D Balance	SN: 39080058	RPL 525 FH

Report Preparer Date

Review and Concurrence Date

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

One liquid sample was submitted under Analytical Service Request (ASR) 1753 and was analyzed by ICP-MS. The sample was diluted prior to analysis in 2% Nitric acid (HNO3).

Results are reported as ng/mL for each detected analyte. The data has been adjusted for instrument dilutions and initial sample dissolution. Initial instrument data is read in ppb (parts per billion).

Deconvolution calculations using natural abundances of Barium isotopes were performed to deduct the amount of Barium -134 and 136 from the Cesium isotopes. The Final results are from the Sample and Sample duplicate ran at the 900X dilution.

Calibration of the ICP-MS was done following the manufacturer's recommended calibration procedure using multi-analyte (natural abundance) custom standard solutions traceable to the National Institute of Standards and Technology (NIST). Midrange calibration verification standards were used to verify acceptance of the six-point calibration curves and for initial and continuing calibration verification (ICV/CCV).

The controlling document was procedure RPG-CMC-292, Rev 1, *Determination of Elemental Composition by Inductively Coupled Argon Plasma Mass Spectrometry (ICP-MS)*. Instrument calibrations, QC checks and blanks (e.g., ICV/ICB, CCV/CCB, LLS, ICS), post-digestion spikes, duplicates, and serial dilutions were conducted during the analysis run.

Internal Standard (IS):

All solutions (blanks, standards, QC checks, and samples) were mixed in-line with a solution containing 10 ppb each of Tb-159 and Bi-209 as the internal standard (IS). The AOI data were normalized to the Tb-159 IS and were within the acceptance criterion of 30% to 120% recovery.

Preparation Blank (PB):

A process blank was not analyzed.

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

A blank spike was not analyzed.

Duplicate/Replicate Relative Percent Difference (RPD)/Relative Standard Deviation (RSD):

A sample replicate of 23-0924 was analyzed, and the results were within the acceptance criterion of ≤20% RPD for the AOI except for Ba-134 which came over the range at 23.0% Difference.

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

Matrix-Spike (MS) Sample:

A matrix spike sample was not analyzed.

Initial/Continuing Calibration Verification (ICV/CCV):

The ICV/CCV solutions (71A) were analyzed immediately after calibration, after each group of not more than ten samples, and at the end of the analytical run. The concentrations of all AOI that bracket the reported results were within the acceptance criteria of 90% to 110% recovery.

Initial/Continuing Calibration Blank (ICB/CCB):

The ICB/CCB solutions (2% v/v HNO_3) were analyzed immediately after each respective ICV solution and after each respective CCV solution (after each group of not more than ten samples and at the end of the analytical run). The concentration of all AOI were within the acceptance criteria of less than EQL.

Post-Digestion Spike (PS)/Analytical Spike (AS) - Sample (P1 Component):

An analytical spike (71A) was conducted on sample 23-0924. All AOI passed on the 71A set. All were within the 75-125% tolerance.

Low-Level Standard (LLS):

The LLS solution (71A) was analyzed immediately after the first CCB solution. The concentrations of all AOI were within the acceptance criteria of 75% to 125%.

Interference Check Standard (ICS):

The ICS solution (71A) was analyzed immediately after the first LLS solution and immediately prior to analyzing the final CCV solutions. The concentrations of all AOI were within the acceptance criteria of 80% to 120% recovery.

Serial Dilution (SD):

A five-fold serial dilution was conducted on the sample. Percent differences (%D) are listed for all analytes that had a concentration at or above 10X the EQL in the diluted sample. The %Ds for the AOI meeting this requirement ranged were within the acceptance criterion of ≤10%.

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

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. 2% 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 71A component (for the AS/PS) are; Ag, Al, As, B, Ba, Be, Ca, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe, Ga, Gd, Ho, K, La, Lu, Mg, Mn, Na, Nd, Ni, P, Pb, Pr, Rb, S, Se, Sm, Sr, Th, Tl, Tm, U, V, Yb, and Zn. Analytes included in the spike 71B component are; Ge, Hf, Mo, Nb, Sb, Si, Sn, Ta, Te, Ti, W, and Zr. Analytes included in the spike 71C component are; Ir, Os, Pd, Pt, Re, Rh, and Ru. Analytes included in the spike 71D component are; Bi, In, Li, Sc, Tb, and Y. Analyte included in the spike Hg component is Hg.
5) Isotopic abundances values were obtained from Nuclides and Isotopes: Chart of the Nuclides. 16th Edition, Revised 2002. Ed Baum, Harold Knox, Tom Miller
6) Analytes included in P1 solution are Ag, Cd, In, Mo, Nb, Pd, Rh, Ru, Sn, Zr.

Sample Results ASR-1673		Run Date >	04/13/23	04/13/23	04/13/23
Isotope Corrected		Dilution Factor >	1.00	900	900
ppb = ng/ml		RPL/LAB >	Blank Avg.	23-0329	23-0329 Rep
Instr. Det. Limit (IDL)	Est. Quant. Limit (EQL)	Client ID >	2% HNO3 Lab Blank	1SY-23-COMP-Cs	
(ng/mL)	(ng/mL)	(Analyte)	(ng/mL)	(ng/mL)	(ng/mL)
0.0001	0.0070	m/z 133	0.000	133.4	132.3
0.0090	0.0950	m/z 135	0.000	26.7	24.8
0.0100	0.0990	m/z 137	0.000	26.4	24.0
0.0010	0.0070	m/z 138	0.000	4.1	0.1

Internal Standard % Recovery

Tb 159 (IS)	101%	99%	103%

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%.
IS = Internal Standard. The concentration of certain elements cannot be determined due to the presence of the IS in all solutions.

QC Performance 4/13/2023

Criteria >	≤ 20%	75%-125%	≤ 10%	
QC ID >	23-0239 Rep 900x	23-0239 Post Spike CCV71A 900x	23-0239 5-fold Serial Dil 150x	
Analytes	RPD (%)	%Rec	%Diff	
m/z 133	1%	98%	4%	
m/z 134	13%	99%	6%	<10x EQL for the Serial Dilution.
m/z 135	1%	96%	4%	
m/z 136	13%	97%	5%	<10x EQL for the Serial Dilution.
m/z 137	1%	97%	5%	
m/z 138	5%	96%	5%	

Internal Standard % Recovery

Tb 159 (IS)	105%	108%	99%

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.
IS = Internal Standard. The concentration of certain elements cannot be determined due to the presence of the IS in all solutions.
NM = Not measured. The isotope was not measure due to method or molecular interference limitations.

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

Project / WP#: 81126 / NP1205
ASR#: 1673
Client: A. Westesen
Total Samples: 1 (liquid)

ASO Sample ID	Client Sample ID	Client Sample Description
23-0331	1SY-23-COMP	SY-101 Tank Waste Supernate

Sample Preparation: Simple dilution of "as received" samples 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)."

Analyst:	C. Perez	**Analysis Date:**	3/23/2023	**ICP File:**	C0901

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: 2023.06.23 14:27:04 -07'00'

Report Preparer — Date

Steven Baum
Digitally signed by Steven Baum
Date: 2023.06.27 12:11:54 -07'00'

Review and Concurrence — Date

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

One aqueous sample was submitted under Analytical Service Request (ASR) 1673 was analyzed by ICP-OES. The sample had an acid digestion performed and was done in combination with samples from ASR 1672.

All sample results are reported on a mass per unit volume basis (µg/mL) 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 highlighted section of the attached ICP-OES Data Report. The quality control (QC) results for the AOI have been evaluated and are presented below.

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.

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. All AOI were within the acceptance criteria of <EQL (estimated quantitation level), <50% regulatory decision level, or less than ≤10% of the concentration in the sample.

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%.

Duplicate/Replicate Relative Percent Difference (RPD):

A Replicate of each sample was prepared and analyzed. RPD are listed for all analytes that were measured at or above the EQL. All AOI were within the acceptance criterion of ≤20% for liquid samples.

Triplicate Relative Standard Deviation (RSD):

No triplicate sample was analyzed.

Matrix-Spike (MS) Sample:

The samples were analyzed "as received" and diluted as appropriate for analyses of the target analytes. A matrix spike sample was generated due to the sample preparation beforehand labeled as MS-23-0331. Potassium (K) and Aluminum (Al) passed on the recovery percentage. Sodium (Na) shows as "nr" on the percentage recovered. This concludes that the spike concentration is <25% of the sample concentration which gives inconclusive results for Sodium.

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%.

Initial/Continuing Calibration Blank (ICB/CCB):

The ICB/CCB solution (5% v/v HNO_3) 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). Sodium (Na) failed on ICP03.0-5 rerun and on the ICP03.0-6 rerun. These two were ran towards the end of the run where the higher concentration of acid digestion was run, which may lead to high concentrations of Na carrying over to the blanks. The ppm concentrations were 0.16 and 0.08 which are slightly above the 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%.

Serial Dilution (SD):

Five-fold serial dilution was conducted on sample 23-0331. The percent difference (%D) for all AOI were withing the acceptance criteria of ≤ 10%.

Post-Digestion Spike (PS-A) - Sample (A Component):

A post-digestion spike (A Component) was conducted on sample 23-0331. All AOI were within the acceptance criterion of 80% to 120%.

Post-Digestion Spike (PS-B) - Sample (B Component):

A post-digestion spike (B Component) was conducted. There were no AOI included in the spike B component.

Post-Digestion Spike (PS-Q3A) - Sample (A Tormont Component):

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

A post-digestion spike (A Tormont Component) was not conducted.

Post-Digestion Spike (PS-Q3B) - Sample (B Tormont Component):

A post-digestion spike (B Tormont Component) was not conducted.

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.

		Run Date >	3/23/2023	3/23/2023	3/23/2023	3/23/2023	3/23/2023	3/23/2023	3/23/2023	3/23/2023
		Process Factor >	1.0	1.0	421.7	421.7	356.8	1054.3	892.0	5271.3
			405 Diluent	23-0326 PB @1x	23-0331 @10x	23-0331 @10x Replicate	23-0331 Dup @10x	23-0331 @25x	23-0331 Dup @25x	23-0331 @125x SRD
Instr. Det. Limit (IDL)	Est. Quant. Limit (EQL)	Client ID >			1SY-23-COMP	1SY-23-COMP	1SY-23-COMP	1SY-23-COMP	1SY-23-COMP	1SY-23-COMP
(µg/mL)	(µg/mL)	(Analyte)	(µg/mL)	(µg/mL)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)
0.0019	0.019	Ag	--	--	--	--	--	--	--	--
0.0101	0.101	Al	--	--	3,350	3,370	2,630	3,340	3,290	3,270
0.0619	0.619	As	--	--	--	--	--	--	--	--
0.0060	0.060	B	[0.038]	[0.033]	[17]	[18]	[11]	[26]	[22]	[150]
0.0001	0.001	Ba	--	0.0078	[0.50]	[0.45]	[0.18]	[0.56]	[0.28]	--
0.0001	0.001	Be	--	--	--	--	--	--	--	--
0.0245	0.245	Bi	--	--	--	--	--	--	--	--
0.0056	0.056	Ca	--	[0.038]	[4.7]	[6.4]	[4.3]	[12]	[20]	[38]
0.0014	0.014	Cd	--	[0.0015]	--	[0.70]	--	--	--	[9.7]
0.0103	0.103	Ce	--	--	--	--	--	--	--	--
0.0043	0.043	Co	--	--	--	--	--	--	--	--
0.0020	0.020	Cr	--	--	97.5	97.9	75.7	99.1	96.3	[100]
0.0023	0.023	Cu	--	--	[2.8]	[2.6]	[1.9]	[2.6]	[3.4]	--
0.0023	0.023	Dy	--	--	--	--	--	--	--	--
0.0006	0.006	Eu	--	--	--	--	--	--	--	--
0.0014	0.014	Fe	--	0.0373	[1.0]	[1.9]	[0.90]	[2.2]	[8.0]	--
0.0312	0.312	K	[0.041]	--	293	282	316	369	327	[530]
0.0019	0.019	La	--	--	--	--	--	--	--	--
0.0007	0.007	Li	--	--	--	--	--	--	--	--
0.0018	0.018	Mg	--	[0.0029]	[0.87]	--	--	--	--	--
0.0002	0.002	Mn	--	--	[0.37]	[0.40]	[0.25]	[0.23]	[0.45]	--
0.0044	0.044	Mo	--	--	[9.4]	[10]	[8.5]	[16]	[11]	[52]
0.0073	0.073	Na	[0.010]	[0.031]	57,500	58,000	45,100	58,400	57,300	59,500
0.0088	0.088	Nd	--	--	--	--	--	--	--	--
0.0022	0.022	Ni	--	[0.0033]	[2.6]	[2.1]	[1.8]	--	[4.1]	--
0.0905	0.905	P	--	--	2,320	2,310	1,760	2,310	2,300	[2,700]
0.0269	0.269	Pb	--	--	--	--	--	--	--	--
0.0054	0.054	Pd	--	--	--	--	--	--	--	--
0.0211	0.211	Rh	--	--	--	--	--	--	--	--
0.0063	0.063	Ru	--	--	--	--	--	--	--	--
0.1262	1.262	S	--	--	650	654	486	[590]	[630]	[1,100]
0.0598	0.598	Sb	--	--	--	--	--	--	--	--
0.1656	1.656	Se	--	--	--	--	--	--	--	--
0.0086	0.086	Si	[0.022]	[0.013]	[4.4]	--	[4.8]	[23]	[16]	[100]
0.0291	0.291	Sn	--	--	--	--	--	--	--	--
0.0001	0.001	Sr	--	[0.0004]	[0.069]	[0.057]	[0.051]	[0.12]	--	--
0.0246	0.246	Ta	--	--	--	--	--	--	--	--
0.0197	0.197	Te	--	--	--	--	--	--	--	--
0.0071	0.071	Th	--	--	--	--	--	--	--	--
0.0006	0.006	Ti	--	[0.0008]	--	--	--	--	--	[3.7]
0.0814	0.814	Tl	--	--	--	--	--	--	--	--
0.0410	0.410	U	--	[0.042]	[19]	--	[16]	--	[59]	[300]
0.0013	0.013	V	[0.0028]	[0.0031]	[2.9]	[2.9]	[2.5]	[4.9]	[4.1]	[13]
0.0161	0.161	W	--	--	--	[6.8]	--	--	--	--
0.0006	0.006	Y	--	--	--	--	--	--	--	--
0.0027	0.027	Zn	--	[0.019]	[2.3]	[2.0]	--	--	--	--
0.0014	0.014	Zr	--	--	--	--	--	--	--	--

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.

		Run Date >	3/23/2023	3/23/2023
		Process Factor >	5271.3	4460.0
			23-0331 @125x SRD Rep.	23-0331 Dup @125x SRD
Instr. Det. Limit (IDL)	Est. Quant. Limit (EQL)	Client ID >	1SY-23-COMP	1SY-23-COMP
(µg/mL)	(µg/mL)	(Analyte)	(µg/g)	(µg/g)
0.0019	0.019	Ag	--	--
0.0101	0.101	Al	3,320	3,330
0.0619	0.619	As	--	--
0.0060	0.060	B	[110]	[65]
0.0001	0.001	Ba	[1.1]	--
0.0001	0.001	Be	--	--
0.0245	0.245	Bi	--	--
0.0056	0.056	Ca	[54]	[64]
0.0014	0.014	Cd	--	--
0.0103	0.103	Ce	--	--
0.0043	0.043	Co	--	--
0.0020	0.020	Cr	107	101
0.0023	0.023	Cu	--	--
0.0023	0.023	Dy	--	--
0.0006	0.006	Eu	--	--
0.0014	0.014	Fe	--	--
0.0312	0.312	K	[540]	[480]
0.0019	0.019	La	--	--
0.0007	0.007	Li	--	--
0.0018	0.018	Mg	--	[11]
0.0002	0.002	Mn	--	--
0.0044	0.044	Mo	--	[29]
0.0073	0.073	Na	59,900	57,900
0.0088	0.088	Nd	--	--
0.0022	0.022	Ni	--	[14]
0.0905	0.905	P	[2,100]	[2,400]
0.0269	0.269	Pb	--	--
0.0054	0.054	Pd	--	--
0.0211	0.211	Rh	--	--
0.0063	0.063	Ru	--	--
0.1262	1.262	S	[780]	--
0.0598	0.598	Sb	--	--
0.1656	1.656	Se	--	--
0.0086	0.086	Si	[60]	[63]
0.0291	0.291	Sn	--	--
0.0001	0.001	Sr	--	--
0.0246	0.246	Ta	--	--
0.0197	0.197	Te	[160]	[120]
0.0071	0.071	Th	--	--
0.0006	0.006	Ti	--	--
0.0814	0.814	Tl	--	--
0.0410	0.410	U	--	--
0.0013	0.013	V	[16]	[14]
0.0161	0.161	W	--	--
0.0006	0.006	Y	--	--
0.0027	0.027	Zn	--	--
0.0014	0.014	Zr	--	--

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.

QC Performance 3/23/2023

Criteria >	≤ 20%	75%-125%	75%-125%	80%-120%	80%-120%	≤ 10%
QC ID >	23-0331 @125x SRD Rep Dup	MS-23-0331 @25x A	MS-23-0331 @25x B	PSA-0331 @25x AS-A	PSB-0331 Dup @25x AS-B	23-0331 @125x SRD 5-Fold Serial Dil
Analytes	RPD (%)	%Rec	%Rec	%Rec	%Rec	%Diff
Ag				103		
Al	1.6	122		107		2.1
As				103		
B			91	110		
Ba		94		105		
Be		99		108		
Bi				105		
Ca		96		107		
Cd		101		111		
Ce		94			103	
Co				108		
Cr		121		104		
Cu		103		110		
Dy					105	
Eu					104	
Fe		93		108		
K		95		105		
La		95			104	
Li		98		110		
Mg		97		107		
Mn		101		110		
Mo			87	104		
Na	0.5	nr		101		2.0
Nd		91			103	
Ni		99		108		
P			184	104		
Pb		101		108		
Pd					99	
Rh					101	
Ru					104	
S			114		101	
Sb				105		
Se				109		
Si				107		
Sn				107		
Sr		97		108		
Ta				108		
Te					104	
Th		96			107	
Ti			41	106		
Tl				101		
U		96			110	
V		94		105		
W				110		
Y				105		
Zn		98		108		
Zr			94	107		

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.

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: _____81126_____
Work Package: _____ NP1214 _____

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

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: NA**
  ☐ Dispose ☐ Return

- ♦ **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

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:___see pg 2_____

- ♦ **Requested Analytical Work Completion Date:**
  _____
  (Note: Priority rate charge for < 10 business day turn-around)
- ♦ **Negotiated Commitment Date:**
  _____**8/4/23**_____
  (***To be completed by ASO Lead***)

Waste Designation Information

- ♦ **ASO Sample Information Check List Attached? X** No ☐ Yes
  If no, Reference Doc Attached: _____
  or, Previous ASR Number: _____1672_____
  or, Previous RPL Number: _____

Does the Waste Designation Documentation Indicate Presence of PCBs?
X 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: __5/11/2023, 5/18/23_____
Delivered By (optional) _____
Time Delivered: _____
Group ID (optional) _____
CMC Waste Sample? **X** No ☐ Yes

Received By: __DW Byram_____

ASR Number: ___1697____Rev.: __01_____
RPL Numbers: 23-0589, 23-0590, 23-0925 to 23-0933
(first and last)

ASO Work Accepted By: _____ **Signature/Date:** _____

ASO Staff Use Only	**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**	**Test**	**Library**
	TI147-Comp-Feed	SY-101 tank waste	1) GEA- All samples (Cs-137, Co-60 and Eu-154 and any other observed gamma emitting isotopes) 2) Tc-99 3) Sr-90 4) Np-AEA, Np-237 5) Pu-AEA, Pu-238, Pu-239/240 6) Am-AEA, Am-241 7) 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		
23-0589					
	TI147-Comp-Eff	SY-101 tank waste- Cs removed	1) GEA- All samples (Cs-137, Co-60 and Eu-154 and any other observed gamma emitting isotopes) 2) IC-Anions- F, Cl, NO_2, NO_3, PO_4, C_2O_4, and SO_4 3) TIC/TOC- Hot Pursulfate 4) OH 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		
23-0590					
23-0925	TI147-L-2-A	SY-101 tank waste- Cs removed Rev1 is issued to correct the client IDs	Sr-90 beta counting		
23-0926	TI147-L-4-A				
23-0927	TI147-L-8-A				
23-0928	TI147-L-10-A				
23-0929	TI147-L-12-A				
23-0930	TI147-L-14-A				
23-0931	TI147-L-17-A				
23-0932	TI147-L-23-A				
23-0933	TI147-L-25-A				

Pacific Northwest National Laboratory
PO Box 999, Richland, WA
Radiochemical Sciences and Engineering Group

filename: 23-0589 Westesen
5/18/2023

Client: Westesen Project: 81126 Prepared by: _____
ASR 1697 WP: NP1214

Technical Reviewer: _____

Procedures: Activity #4468- Gamma Energy Analysis (GEA) and Low-Energy Photon Spectrometry (LEPS)
M&TE: Gamma detector G,
Count dates: 12-May-23

Measured Activity, Bq per sample ± 1s

Count ID	G9744		G9745	
RPL ID:	23-0589		23-0590	
Sample ID:	**TI47 Comp Feed**		**TI47 Comp EFF**	
Isotope		±		±
Cs-137	**3.84E+06**	**± 2%**	**1.03E+03**	**± 2%**
Co-60	< 6.5E+0		**1.15E+01**	**± 2%**
Eu-154	< 5.1E+1		< 3.2E-1	
Sn-126	< 2.2E+2		**4.21E+01**	**± 2%**
Sb-126	< 6.1E+1		**3.58E+01**	**± 2%**

Client	**Westesen**				
Work Order #		**Procedure**	**LA Activity 7898**	**Balance #**	**1113162654 exp 2/24**
ASR #	**1697**		OH-	**Temperature**	**20.6**

Sample #'s	Tare (g)	+Sample (g)	+NaOH (g)	Burette Start (mL)	Burette End (mL)	Sample mass (g)	Spike mass (g)	Total liquid mass titrated (g)	Total volume needed to titrate (mL)	Volume sample titrated (mL)
23-0590	16.3753	16.6019		1.08	3.40	0.2266		0.2266	2.32	0.1976
23-0590 Dup	16.3478	16.5774		3.40	5.59	0.2296		0.2296	2.19	0.2002
23-0590 MS	16.3705	16.6023	17.1089	5.59	8.20	0.2318	0.5066	0.7384	2.61	0.2022
23-0590 BS	16.3032		16.8093	8.20	8.75		0.5061	0.5061	0.55	
23-0590 PB	16.3937			8.75	8.80			0.0000	0.05	

	M OH	Average	Stdev.S	%RSD
23-0590	1.2740	1.1989	0.0698044	5.8221
23-0590 Dup	1.1869			
23-0590 MS	1.1360			
23-0590 BS	0.1194			

Sample Density Calculation

replicate	grams dispensed	g/mL	g/mL	
1	0.2266	1.1330	1.1467	Avg
2	0.2296	1.1480	0.013051	Stdev.s
3	0.2318	1.1590	1.138%	%RSD

dispensing 0.2000 mL sample via pipette L16204F and balance 1113162654

Notes: Acid used was 98620A-7-2. Used pipette L16204F sat @ 0.2 mL for sample & 0.5 mL for spike. PB was only water. Samples titrated to a pH of 7 via LA Activity 7897 - Measurement of pH in aqueous solution.

Spike/Tracer ID		98620A-7-3								
Isotope		n/a		Vol Used (mL)				Vol Used (mL)		
Concentration		0.1072 M NaOH		0.5000						
Reference Date		3/20/2023								
Expiration Date		3/20/2024								

Analyst/Date _____ **Reviewer/Date** _____

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

Project / WP#: 88126 / NP1214
ASR#: 1697
Client: A. Westesen
Total Samples: 4 (liquids)

ASO Sample ID	Client Sample ID	Client Sample Description
23-0589	TI147-Comp-Feed	SY-101 tank waste
23-0590	TI147-Comp-Eff	SY-101 tank waste – Cs removed

Sample Preparation: Simple dilution of "as received" samples 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)."

Analyst:	C. Perez	**Analysis Date:**	7/28/2023	**ICP File:**	C0908

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

Report Preparer _____ Date _____

Review and Concurrence _____ Date _____

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

Two liquid samples were submitted under Analytical Service Request (ASR) 1697 and were analyzed by ICP-OES. The samples had an acid digestion performed by the Radiochemistry team.

All sample results are reported on a mass per 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 highlighted section of the attached ICP-OES Data Report. The quality control (QC) results for the AOI have been evaluated and are presented below.

Limited Data:
An incorrect spike was used for the digestion process and did not include the following analytes.

For sample 23-0589 (TI147-Comp-Feed) data, Arsenic (As), Phosphorus (P), Sulfur (S), Titanium (Ti), Uranium (U), and Zirconium (Zr) is for reference only.

For sample 23-0590 (TI147-Comp-Eff) data, Arsenic (As), Phosphorus (P), Sulfur (S), Uranium (U) and Zirconium (Zr) is for reference only.

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.

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. All AOI except for Barium (Ba) and Sodium (Na) were within the acceptance criteria of <EQL (estimated quantitation level), <50% regulatory decision level, or less than ≤10% of the concentration in the sample. Both were very low levels and just above the EQL. Sodium (Na) was high due to the use of 3M NaOH as the matrix for the Preparation Blank.

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 23-0589 BS-A @10x, Sodium is reported as "nr" due to the spike being less than 25% of the sample concentration. Arsenic, Phosphorus, Sulfur, Titanium, Uranium, and Zirconium were not included in the spike due to using an incorrect spike solution. All other AOI, except aluminum and chromium, passed and were within the acceptance criteria of 75-25%., Aluminum and Chromium underperformed which may be due to a digestion issue with the matrix.

For 23-0590 BS-A @10x, Aluminum and Chromium show as "nr" due to the spike being less than 25% of the sample concentration. Sodium is reported as "nr" due to the spike being less than 25% of the sample concentration. Arsenic, Phosphorus, Sulfur, Titanium, Uranium and Zirconium were not included in the spike due to using an incorrect spike solution. All other AOI passed and were in between 75-125% recovery. Potassium failed with a recovery of 33%. This may be due a digestion issue with the matrix.

For 23-0590 BS-B @10x, Titanium and Zirconium were included in the spike solution. Zirconium failed at 68% recovery. The low-recovery may be due to the small spike amount or matrix issue. Titanium passed with 80% recovery.

Duplicate/Replicate Relative Percent Difference (RPD):

A duplicate of sample 23-0589 @10x was prepared and analyzed. RPD are listed for all analytes that were measured at or above the EQL. All AOI detected were within the acceptance criterion of ≤20% for liquid samples.

Triplicate Relative Standard Deviation (RSD):

No triplicate sample was analyzed.

Matrix-Spike (MS) Sample:

The samples were analyzed "as received" and diluted as appropriate for analyses of the target analytes. A matrix spike sample was created during sample preparation beforehand.

For 23-0589 MS-A @10x, Sodium is reported as "nr" due to the spike being less than 25% of the sample concentration. Arsenic, Phosphorus, Sulfur, Titanium, Uranium, and Zirconium were not included in the spike due to using an incorrect spike solution. All other AOI passed and were in between 75-125% recovery.

For 23-0590 MS-A @10x, Aluminum, Chromium and Sodium are reported as "nr" due to the spike being less than 25% of the sample concentration. Arsenic, Phosphorus, Sulfur, Titanium, Uranium and Zirconium were not included in the spike due to using an incorrect spike solution. All other AOI passed and were in between 75-125% recovery.

For 23-0590 MS-B @10x, Titanium and Zirconium were included in the spike solution. Zirconium failed at 69% recovery. The low-recovery may be due to the small spike amount or matrix issue. Titanium passed with 86% recovery.

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%.

Initial/Continuing Calibration Blank (ICB/CCB):

The ICB/CCB solution (5% v/v HNO_3) 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 passed on the ICB/CCBs ran.

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%.

Serial Dilution (SD):

Five-fold serial dilution was conducted on sample 23-0589 Duplicate. The percent difference (%D) for all AOI were withing the acceptance criteria of ≤ 10%.

Post-Digestion Spike (PS-A) - Sample (A Component):

A post-digestion spike (A Component) was conducted on sample 23-0589 @25x. All AOI were within the acceptance criterion of 80% to 120%.

Post-Digestion Spike (PS-B) - Sample (B Component):

A post-digestion spike (B Component) was conducted on sample 23-0590 @25x. 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 MCVA 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 MCVB component are; Ce, Dy, Eu, La, Nd, Pd, Rh, Ru, S, Te, Th, and U.

		Run Date >	7/28/2023	7/28/2023	7/28/2023	7/28/2023	7/28/2023	7/28/2023	7/28/2023	7/28/2023	7/28/2023	7/28/2023	7/28/2023
		Process Factor >	1.0	1.0	206.3	543.6	2632.3	201.6	537.4	2611.5	198.9	524.0	2537.5
			405 Diluent	23-0589 PB @1x	23-0589 @10x	23-0589 @25x	23-0589 @125x SRD	23-0589 Dup @10x	23-0589 Dup @25x	23-0589 Dup @125x SRD	23-0590 @10x	23-0590 @25x	23-0590 @125x SRD
Instr. Det. Limit (IDL)	Est. Quant. Limit (EQL)	Client ID >			TI147-Comp-Feed			TI147-Comp-Feed			TI147-Comp-Eff		
(µg/mL)	(µg/mL)	(Analyte)	(µg/mL)	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g
0.0101	0.101	Al	--	--	2,900	3,110	2,970	2,880	3,110	3,000	2,910	3,150	3,050
0.0619	0.619	As	--	--	--	--	--	--	--	--	--	--	--
0.0001	0.001	Ba	--	0.0117	[0.12]	--	--	--	--	--	--	--	--
0.0056	0.056	Ca	--	--	[6.4]	--	--	[3.4]	--	--	[2.5]	[17]	--
0.0014	0.014	Cd	[0.0023]	--	[0.40]	[1.7]	--	--	[1.5]	[10]	--	--	--
0.0020	0.020	Cr	--	--	92.3	100	95.0	92.8	99.2	99.0	88.3	96.0	93.1
0.0014	0.014	Fe	--	[0.012]	--	--	--	[2.0]	--	--	--	--	--
0.0312	0.312	K	--	--	279	304	879	278	284	[610]	261	275	[490]
0.0073	0.073	Na	--	over-range	53,700	58,200	59,000	53,100	58,000	58,800	52,400	56,200	55,100
0.0022	0.022	Ni	--	--	4.86	--	--	--	--	--	--	--	--
0.0905	0.905	P	--	--	2,150	2,310	[2,300]	2,190	2,330	[2,200]	2,080	2,250	[2,200]
0.0269	0.269	Pb	--	--	--	--	--	--	--	--	--	--	--
0.1262	1.262	S	--	[0.22]	632	873	[970]	700	879	[1,900]	657	808	[1,400]
0.0001	0.001	Sr	--	[0.0006]	[0.030]	--	--	--	--	--	--	--	--
0.0006	0.006	Ti	--	--	--	--	--	--	--	--	--	--	--
0.0410	0.410	U	--	--	--	--	--	--	--	--	--	--	--
0.0027	0.027	Zn	--	[0.012]	--	--	--	--	--	--	--	--	--
0.0014	0.014	Zr	--	--	--	--	--	--	--	--	[0.48]	--	--
Other Analytes													
0.0019	0.019	Ag	--	--	--	--	--	--	--	--	--	--	--
0.0060	0.060	B	--	--	27.8	[19]	--	24.2	[12]	--	--	--	--
0.0001	0.001	Be	--	--	--	--	--	--	--	--	--	--	--
0.0245	0.245	Bi	--	--	--	--	--	--	--	--	--	--	--
0.0103	0.103	Ce	--	--	--	--	--	--	--	--	--	--	--
0.0043	0.043	Co	--	--	--	--	--	--	--	--	--	--	--
0.0023	0.023	Cu	--	0.0652	[2.1]	[2.0]	--	[1.7]	[1.3]	--	[1.9]	--	--
0.0023	0.023	Dy	--	--	--	--	--	--	--	--	--	--	[6.0]
0.0006	0.006	Eu	--	--	[0.14]	--	[2.0]	--	--	--	--	--	--
0.0019	0.019	La	--	--	--	--	--	--	--	--	--	--	--
0.0007	0.007	Li	--	[0.0032]	[0.43]	[0.59]	[2.4]	[0.42]	--	[2.4]	[0.36]	--	--
0.0018	0.018	Mg	--	--	--	--	--	--	--	--	--	--	--
0.0002	0.002	Mn	--	0.0123	[0.39]	[0.24]	--	[0.39]	[0.31]	--	[0.35]	[0.21]	--
0.0044	0.044	Mo	[0.013]	[0.0061]	10.2	[13]	--	9.35	[13]	[27]	10.2	[12]	[25]
0.0088	0.088	Nd	--	--	--	--	--	--	--	--	--	--	--
0.0054	0.054	Pd	--	--	[1.4]	--	[20]	--	[3.4]	--	[1.9]	[6.5]	--
0.0211	0.211	Rh	--	--	--	--	--	--	--	--	--	--	--
0.0063	0.063	Ru	--	--	--	--	--	--	--	--	--	--	--
0.0598	0.598	Sb	--	--	--	--	--	--	--	--	--	--	--
0.1656	1.656	Se	--	--	--	--	--	--	--	--	--	--	--
0.0086	0.086	Si	--	--	42.5	[9.3]	--	41.4	[7.2]	--	--	--	--
0.0291	0.291	Sn	--	[0.029]	--	--	--	[6.1]	--	--	--	[17]	--
0.0246	0.246	Ta	--	--	--	--	--	--	--	--	--	--	--
0.0197	0.197	Te	--	--	--	--	--	--	--	--	--	--	--
0.0071	0.071	Th	--	[0.010]	--	[4.1]	[19]	--	--	--	--	--	--
0.0814	0.814	Tl	--	--	--	--	--	--	--	--	--	--	--
0.0013	0.013	V	[0.0025]	[0.0034]	[1.6]	[3.0]	[4.2]	[1.7]	[2.7]	[5.8]	[1.6]	[2.8]	--
0.0161	0.161	W	--	--	[8.0]	--	--	[7.2]	--	--	[5.8]	--	--
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.

QC Performance 7/28/2023

Criteria >	≤ 20%	80%-120%	75%-125%	75%-125%	75%-125%	80%-120%	80%-120%	≤ 10%	≤ 10%
QC ID >	23-0589 @10x Dup	LCS/BS	23-0589 @10x A MS	23-0590 @10x A MS	23-0590 @10x B MS	23-0589 @25x + PS-A	23-0590 @25x + AS-B	23-0589 Dup @125x 5-fold Serial Dil	23-0590 @125x 5-fold Serial Dil
Analytes	RPD (%)	%Rec	%Rec	%Rec	%Rec	%Rec	%Rec	%Diff	%Diff
Al	1.6	102	91	nr		103		0.8	0.1
As		101				100			
Ba		101	89	88		102			
Ca		103	91	94		104			
Cd		103	94	101		105			
Cr	2.9	99	92	nr		100		2.7	0.2
Fe		105	89	88		105			
K	1.7	101	92	91		103			
Na	1.2	103	nr	nr		102		4.4	1.3
Ni		104	87	88		103			
P	3.9	103				102			
Pb		102	90			103			
S	12.6	100					98		
Sr		100	82	81		96			
Ti		102			86	103			
U		102					101		
Zn		100	91			103			
Zr		101			69	102			
Other Analytes									
Ag		96				94			
B	11.8	102				101			
Be		104	90	86		102			
Bi		96				98			
Ce		98	83				98		
Co		103				103			
Cu		110	94	92		107			
Dy		100					99		
Eu		99					98		
La		98	85	83			97		
Li		107	93	86		105			
Mg		104	91	89		105			
Mn		107	91	89		105			
Mo	6.4	100			70	99			
Nd		98	85	85			98		
Pd		93					93		
Rh		97					97		
Ru		96					98		
Sb		97				99			
Se		101				102			
Si	0.3	102				104			
Sn		99				100			
Ta		102				100			
Te		99					99		
Th		100					100		
Tl		93				93			
V		100	88	86		101			
W		98				100			
Y		101				101			

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.

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

Project / WP#: **81126** / NP1214 **ASR#:** 1697
Client Name: **A. Westesen** **Total Samples:** **1** (liquid)
Client Sample Description: **SY-101 Tank Waste – Cs removed**

ASO Sample ID	**Client Sample ID**
23-0590	TI147-Comp-Eff

Sample Preparation: Simple dilution of sample in 2% v/v HNO_3 was performed by C. Perez on 8/1/2023.

Procedure: RPG-CMC-292, Rev. 1, "Determination of Elemental Composition by Inductively Coupled Argon Plasma Mass Spectrometry (ICP-MS)."

Analyst(s):	C.Perez	**Analysis Date:**	8/2/2023	**ICP File:**	M0334

See Chemical Measurement Center 98620 file: ICP-MS-325-405-1
(Calibration and Maintenance Records)

M&TE:			
☒	PerkinElmer NexION™ 350X ICP-MS	SN: 85VN4070702	RPL 405
☒	Ohaus PA224C Balance	SN: B725287790	RPL 405
☒	Mettler AT400 Balance	SN: M19445	RPL 405 FH
☐	Mettler AT400 Balance	SN: 1113162654	RPL 420 FH
☐	Mettler AT400 Balance	SN: 1113292667	RPL 420 FH
☐	Sartorius R200D Balance	SN: 39080058	RPL 525 FH

Report Preparer Date

Review and Concurrence Date

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

One liquid sample was submitted under Analytical Service Request (ASR) 1697 and was analyzed by ICP-MS. The sample went through an acid digestion process and was then diluted prior to analysis.

Results are reported as ng/g for each detected analyte. The data has been adjusted for instrument dilutions and initial sample dissolution. Initial instrument data is read in ppb (parts per billion). Strontium-88, Barium-137 and Barium-138 came back under the lower calibration limit. The data for Sr-88, Ba-137 and Ba-138 has high uncertainty due this very low concentration.

Limited Data:
An incorrect spike was used for the digestion process and did not include the following analytes.

Uranium was not included in the Matrix Spike and Blank Spike solutions. The Uranium data should only be used as reference only for the ICP-MS results.

Calibration of the ICP-MS was done following the manufacturer's recommended calibration procedure using multi-analyte (natural abundance) custom standard solutions traceable to the National Institute of Standards and Technology (NIST). Midrange calibration verification standards were used to verify acceptance of the six-point calibration curves and for initial and continuing calibration verification (ICV/CCV).

The controlling document was procedure RPG-CMC-292, Rev 1, *Determination of Elemental Composition by Inductively Coupled Argon Plasma Mass Spectrometry (ICP-MS)*. Instrument calibrations, QC checks and blanks (e.g., ICV/ICB, CCV/CCB, LLS, ICS), post-digestion spikes, duplicates, and serial dilutions were conducted during the analysis run.

Internal Standard (IS):

All solutions (blanks, standards, QC checks, and samples) were mixed in-line with a solution containing 10 ppb each of Tb-159 and Bi-209 as the internal standard (IS). The AOI data were normalized to the Tb-159 IS and were within the acceptance criterion of 30% to 120% recovery.

Preparation Blank (PB):

A preparation (process) blank was analyzed at a 30x dilution to match the dilution of the sample. Sr-88, Ba-137 and Ba-138 blank results were slightly above the EQL. The sample results were similar to the blank which shows possible blank contamination for the analytes. All other AOIs in the prep blank were either less than EQL or less than 5% of the sample concentration.

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

A blank spike at 30X was analyzed and all AOI passed except for Niobium which had a recovery of 73%, and Uranium. Uranium was not in the spike solutions, and therefore the Uranium data should only be used as reference only. Niobium may be slightly lower due to stability effects and not having the HF acid added prior to digestion.

Duplicate/Replicate Relative Percent Difference (RPD)/Relative Standard Deviation (RSD):

A sample replicate of 23-0590 @ 30x was analyzed, and the results were within the acceptance criterion of ≤20% RPD for liquid samples except for Uranium which failed with a recovery of 26.5%.

Matrix-Spike (MS) Sample:

A matrix spike at 30X was analyzed and all AOI passed except for Uranium. Uranium was not in the spike solutions, and therefore the Uranium data should only be used as reference only.

Initial/Continuing Calibration Verification (ICV/CCV):

The ICV/CCV solutions (71A) were analyzed immediately after calibration, after each group of not more than ten samples, and at the end of the analytical run. The concentrations of all AOI that bracket the reported results were within the acceptance criteria of 90% to 110% recovery.

Initial/Continuing Calibration Blank (ICB/CCB):

The ICB/CCB solutions (2% v/v HNO_3) were analyzed immediately after each respective ICV solution and after each respective CCV solution (after each group of not more than ten samples and at the end of the analytical run). The concentration of all AOI were within the acceptance criteria of less than EQL.

Post-Digestion Spike (PS)/Analytical Spike (AS) - Sample (P1 Component):

Post-digestion spikes 71A and 71B were conducted on sample 23-0590. All AOIs were observed within the recovery limits for the 30X dilution except for Pb-206, Pb-207, Pb-208 and U-238. All AOI passed on the 71A and 71B sets for this the 900X dilution. This may indicate slight matrix affects or mishandled sample preparation to the 30X dilution.

Low-Level Standard (LLS):

The LLS solutions of 71A and 71B were analyzed immediately after the first CCB solution. The concentrations of all AOI were within the acceptance criteria of 75% to 125%.

Interference Check Standard (ICS):

The ICS solutions 71A and 71B were analyzed immediately after the first LLS solution and immediately prior to analyzing the final CCV solutions. The concentrations of all AOI were within the acceptance criteria of 80% to 120% recovery.

Serial Dilution (SD):

A five-fold serial dilution was conducted on both samples. Percent differences (%D) are listed for all analytes that had a concentration at or above 10X the EQL in the diluted sample. The %Ds for the AOI meeting this requirement were within the acceptance criterion of ≤10%. The sample 23-0590 at 150X dilution was used due to measurement of the most AOIs within the calibration limits. Sr-88, Ba-137 and Ba-138 were all less than 10X the EQL.

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

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. 2% 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 71A component (for the AS/PS) are; Ag, Al, As, B, Ba, Be, Ca, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe, Ga, Gd, Ho, K, La, Lu, Mg, Mn, Na, Nd, Ni, P, Pb, Pr, Rb, S, Se, Sm, Sr, Th, Tl, Tm, U, V, Yb, and Zn. Analytes included in the spike 71B component are; Ge, Hf, Mo, Nb, Sb, Si, Sn, Ta, Te, Ti, W, and Zr. Analytes included in the spike 71C component are; Ir, Os, Pd, Pt, Re, Rh, and Ru. Analytes included in the spike 71D component are; Bi, In, Li, Sc, Tb, and Y. Analyte included in the spike Hg component is Hg.
5) Isotopic abundances values were obtained from Nuclides and Isotopes: Chart of the Nuclides. 16th Edition, Revised 2002. Ed Baum, Harold Knox, Tom Miller
6) Analytes included in P1 solution are Ag, Cd, In, Mo, Nb, Pd, Rh, Ru, Sn, Zr.

Units: ng/g		Run Date >	08/02/23	08/02/23	08/02/23	
		Process Factor	1.00	569	569	
		RPL/LAB >	Blank Avg.	23-0590 (30x)	23-0590 (30x) Dup	
Instr. Det. Limit (IDL)	Est. Quant. Limit (EQL)	Client ID >	2% HNO3 Lab Blank	TI147-Comp-Eff		
0.0022	0.0223	Sr 88	0.001	35.8	79.8	**Less than the lower calibration limit.**
0.0056	0.0561	Ba 137	0.001	32.9	121.3	**Less than the lower calibration limit.**
0.0007	0.0072	Ba 138	0.000	30.5	114.5	**Less than the lower calibration limit.**
0.0045	0.0452	Pb 206	0.001	959.4	889.8	
0.0057	0.0573	Pb 207	0.000	921.2	861.5	
0.0028	0.0289	Pb 208	0.000	914.0	863.2	
0.0002	0.0024	U 238	-0.001	2313.6	1706.5	**Uranium not included in the Pre-Digestion Spikes.**

Internal Standard % Recovery			
Tb 159 (IS)	94%	96%	99%

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
times the "multiplier". Overall error for values ≥ EQL is estimated to be within ±15%.
IS = Internal Standard. The concentration of certain elements cannot be determined due to the presence of the IS in all solutions.

QC Performance 8/2/23

Criteria >	≤ 35%	75%-125%	75%-125%	≤ 10%	75%-125%	75%-125%
QC ID >	23-0590 Dup 30x	23-0590 Post Spike ICPMS-71A 30x	23-0590 Post Spike ICPMS-71A 900x	23-0590 5-fold Serial Dil 150x	23-0590 MS 30x	23-0590 BS 30x
Analytes	RPD (%)	%Rec	%Rec	%Diff	%Rec	%Rec
Sr 88	79.3%	93.2%		46.6%	84.9%	84.2%
Ba 137	117.3%	95.7%		49.4%	87.7%	90.4%
Ba 138	118.4%	94.2%		52.4%	85.8%	89.4%
Pb 206	3.7%		96.8%	0.7%	84.1%	86.1%
Pb 207	2.9%		97.1%	1.6%	87.1%	88.6%
Pb 208	1.9%		98.5%	1.0%	85.0%	85.9%
U 238	26.5%		93.7%	0.7%	N/A	N/A

Internal Standard % Recovery						
Tb 159 (IS)	99%	99%	97%	102%	102%	100%

Conc. Is less than 10X the EQL for the Serial Dilution on Sr-88 and Ba-137-138
Uranium was not included in the spike solutions.

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 Na2O2 flux and Zr crucible for fusion preparations, or Si for HF assisted digests
IS = Internal Standard. The concentration of certain elements cannot be determined due to the presence of the IS in all solutions.
NM = Not measured. The isotope was not measure due to method or molecular interference limitations.

		Run Date >	08/02/23	08/02/23	08/02/23
		Process Factor	1.00	645	621
ppb = ng/g		RPL/LAB >	Blank Avg.	23-0590 (30x)	23-0590 (30x) Dup
Instr. Det. Limit (IDL)	Est. Quant. Limit (EQL)	Client ID >	2% HNO3 Lab Blank	TI139-Comp-Eff	
0.0010	0.0060	Nb 93	-0.001	206.7	152.2
		Internal Standard % Recovery			
		Tb 159 (IS)	99%	103%	97%

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
times the "multiplier". Overall error for values ≥ EQL is estimated to be within ±15%.
IS = Internal Standard. The concentration of certain elements cannot be determined due to the presence of the IS in all solutions.

QC Performance 8/2/23

Criteria >	≤ 35%	75%-125%	≤ 10%
QC ID >	23-0590 Dup 30x	23-0590 Post Spike ICPMS-71B 30x	23-0590 5-fold Serial Dil 150x
Analytes	RPD (%)	%Rec	%Diff
Nb 93	0.5%	83.8%	0.5%

Internal Standard % Recovery

Tb 159 (IS)	97%	105%	101%

Conc. Is less than 10X the EQL for the Serial Dilution on Sr-88 and Ba-137-138
Uranium was not included in the spike solutions.

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 Na2O2 flux and Zr crucible for fusion preparations, or Si for HF assisted digests
IS = Internal Standard. The concentration of certain elements cannot be determined due to the presence of the IS in all solutions.
NM = Not measured. The isotope was not measure due to method or molecular interference limitations.

Client ID: TI147-Comp-Eff

PRELIMINARY

Sample Name	Flouride	Chloride	Nitrite	Sulfate
23-0590 @25x	353	850	10173	56986
23-0590 @100x	246	829	11098	57893
23-0590 @500x srd	< MDL	777	10499	54230
23-0590 @1000x	< MDL	776	9301	48747
23-0590 @5000x srd	< MDL	1218	7907	48272
23-0590 Dup @25x	346	831	9949	55585
23-0590 Dup @100x	237	786	10487	54785
23-0590 Dup @500x srd	< MDL	862	11671	60264
23-0590 Dup @1000x	< MDL	718	8769	45881
23-0590 Dup @5000x srd	< MDL	1104	7616	46243
23-0590 PB @1x	< MDL	< MDL	< MDL	< MDL
23-0590 PB @10x	< MDL	< MDL	< MDL	< MDL

All data is in ppm and Total Process Factor Corrected.
All data for reference only.

Sample Name	Bromide	Oxalate	Nitrate	Phosphate
23-0590 @25x	< MDL	1823	1700	6469
23-0590 @100x	< MDL	1612	1524	6081
23-0590 @500x srd	< MDL	615	1552	5628
23-0590 @1000x	< MDL	< MDL	1812	4782
23-0590 @5000x srd	< MDL	< MDL	4325	12466
23-0590 Dup @25x	< MDL	1760	1650	6387
23-0590 Dup @100x	< MDL	1522	1436	5832
23-0590 Dup @500x srd	< MDL	686	1713	6415
23-0590 Dup @1000x	< MDL	< MDL	1617	4390
23-0590 Dup @5000x srd	< MDL	< MDL	4075	9061
23-0590 PB @1x	< MDL	< MDL	< MDL	0.185
23-0590 PB @10x	< MDL	< MDL	< MDL	< MDL

PRELIMINARY

Chain of Custody (COC) Form

1. Chain of Custody # COC-DFTP-012	2. Project No./Title 81126: High Level Waste Test Bed (SY-101)	3. Analyses							4. Project Point of Contact Amy Westesen Amy.Westesen@pnnl.gov	5. Phone No. 509-371-7908
6. Scope of Work Document(s) PNNL REQ# 762164, Task Order 681375, **SWRI Master Agreement 660825**		ICP-AES	Alpha Spec (Am, Cm, Np, & Pu)	ICP-MS (Cs, I, & Tc)	IC (total fusion)	TOC	TIC	Alpha Spec (Am, Cm, Np, & Pu)		

7. Date	8. Time	9. Sample Identification	10. # Cont.	ICP-AES	Alpha Spec (Am, Cm, Np, & Pu)	ICP-MS (Cs, I, & Tc)	IC (total fusion)	TOC	TIC	Alpha Spec (Am, Cm, Np, & Pu)	11. Matrix	12. Comments
		TI147-L-1	1	X	X	X					Aqueous	pH = 14
		TI147-L-3	1	X	X	X					Aqueous	pH = 14
		TI147-L-5	1	X	X	X					Aqueous	pH = 14
		TI147-L-7	1	X	X	X					Aqueous	pH = 14
		TI147-L-9	1	X	X	X					Aqueous	pH = 14
		TI147-L-11	1	X	X	X					Aqueous	pH = 14
		TI147-L-13	1	X	X	X					Aqueous	pH = 14
		TI147-L-15	1	X	X	X					Aqueous	pH = 14
		TI147-P-1	1	X	X	X					Aqueous	pH = 14
		TI147-P-3	1	X	X	X					Aqueous	pH = 14
		TI147-P-5	1	X	X	X					Aqueous	pH = 14
		TI147-P-7	1	X	X	X					Aqueous	pH = 14
		TI147-P-9	1	X	X	X					Aqueous	pH = 14
		TI147-P-11	1	X	X	X					Aqueous	pH = 14

Client: Battelle Memorial Institute PNNL
SRR # 69508
Project # 27927.03.001
Case: 600825
VTSR: 04/24/23
Sample(s) Received: Intact
Temperature: 19.8°C SN # 029926

13. Final Sample Disposition: Dispose on-site	14.	15. Samples Preserved? No[x] If "Yes", then note preservation in Box 14.

16. Sample Custodians

Date	Time	Relinquished by	Date	Time	Received by
4/21/23	11:00	amy westesen	04.24.23	09:30	David Mann
Date	Time	Relinquished by	Date	Time	Received by
Date	Time	Relinquished by	Date	Time	Received by
Date	Time	Relinquished by	Date	Time	Received by
Date	Time	Relinquished by	Date	Time	Received by
Date	Time	Relinquished by	Date	Time	Received by

Client: Battelle Memorial Institute PNNL
SRR # 69508
Project # 27927.03.001
Case: 600825
VTSR: 04/24/23
Sample(s) Received: Intact
Temperature: 19.8°C SN # 029926

Client: Battelle Memorial Institute PNNL
Task Order: 230424-6

SDG: 704601
SRR: 69508

Case: 600825
Project: 27927.03.001

Client Sample ID	Lab Sample ID
TI147-L-1	704601
TI147-L-11	704602
TI147-L-13	704603
TI147-L-15	704604
TI147-L-3	704605
TI147-L-5	704606
TI147-L-7	704607
TI147-L-9	704608
TI147-P-1	704609
TI147-P-11	704610
TI147-P-3	704611
TI147-P-5	704612
TI147-P-7	704613
TI147-P-9	704614

Comments:

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
T147-L-1

Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230424-6
Lab ID: 704601
Result Units: mg/Kg

SDG: 704601
SRR: 69508
Matrix: Aqueous
% Solids: NA

Case: 600825
Project: 27927.03.001
Receipt Date: 04/24/2023
Collection Date: NA

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	2,870	D	P1	89.6	179	10	20230503-P003	05/10/2023 11:58
7440-36-0	Antimony	2.24	U	P1	2.24	4.48	1	20230503-P003	05/10/2023 13:59
7440-38-2	Arsenic	2.24	U	P1	2.24	4.48	1	20230503-P003	05/10/2023 13:59
7440-39-3	Barium	0.448	U	P1	0.448	0.896	1	20230503-P003	05/10/2023 13:59
7440-41-7	Beryllium	0.448	U	P1	0.448	0.896	1	20230503-P003	05/10/2023 13:59
7440-69-9	Bismuth	3.58	U	P1	3.58	7.17	1	20230503-P003	05/10/2023 13:59
7440-42-8	Boron	9.70	J	P1	8.96	17.9	1	20230503-P003	05/10/2023 13:59
7440-43-9	Cadmium	0.448	U	P1	0.448	0.896	1	20230503-P003	05/10/2023 13:59
7440-70-2	Calcium	6.77	J	P1	4.48	8.96	1	20230503-P003	05/10/2023 13:59
7440-46-2	Cesium	0.448	UD	MS2	0.448	0.896	10	20230503-P003	05/11/2023 18:15
7440-47-3	Chromium	90.1		P1	0.448	0.896	1	20230503-P003	05/10/2023 13:59
7440-48-4	Cobalt	0.448	U	P1	0.448	0.896	1	20230503-P003	05/10/2023 13:59
7440-50-8	Copper	0.448	U	P1	0.448	0.896	1	20230503-P003	05/10/2023 13:59
7439-89-6	Iron	8.96	U	P1	8.96	17.9	1	20230503-P003	05/10/2023 13:59
7439-91-0	Lanthanum	1.34	U	P1	1.34	2.69	1	20230503-P003	05/10/2023 13:59
7439-92-1	Lead	0.672	U	P1	0.672	1.34	1	20230503-P003	05/10/2023 13:59
7439-93-2	Lithium	1.34	U	P3	1.34	2.69	1	20230503-P003	05/10/2023 15:17
7439-95-4	Magnesium	4.48	U	P1	4.48	8.96	1	20230503-P003	05/10/2023 13:59
7439-96-5	Manganese	0.448	U	P1	0.448	0.896	1	20230503-P003	05/10/2023 13:59
7439-98-7	Molybdenum	9.00		P1	0.896	1.79	1	20230503-P003	05/10/2023 13:59
7440-02-0	Nickel	1.08		P1	0.448	0.896	1	20230503-P003	05/10/2023 13:59
7440-05-3	Palladium	2.24	U	P1	2.24	4.48	1	20230503-P003	05/10/2023 13:59
7723-14-0	Phosphorus	2,220	D	P1	112	224	10	20230503-P003	05/10/2023 11:58
7440-09-7	Potassium	51.8		P3	13.4	26.9	1	20230503-P003	05/10/2023 15:17
7782-49-2	Selenium	2.24	U	P1	2.24	4.48	1	20230503-P003	05/10/2023 13:59
7440-21-3	Silicon	42.6		P1	11.2	22.4	1	20230503-P003	05/10/2023 13:59
7440-22-4	Silver	0.896	U	P1	0.896	1.79	1	20230503-P003	05/10/2023 13:59
7440-23-5	Sodium	53,600	D	P3	134	269	10	20230503-P003	05/10/2023 14:42
7440-24-6	Strontium	0.448	U	P1	0.448	0.896	1	20230503-P003	05/10/2023 13:59
7704-34-9	Sulfur	595	D	P1	67.2	134	10	20230503-P003	05/10/2023 11:58
7440-28-0	Thallium	6.72	U	P1	6.72	13.4	1	20230503-P003	05/10/2023 13:59
7440-29-1	Thorium	2.24	U	P1	2.24	4.48	1	20230503-P003	05/10/2023 13:59
7440-31-5	Tin	1.91	J	P1	1.79	3.58	1	20230503-P003	05/10/2023 13:59
7440-32-6	Titanium	0.448	U	P1	0.448	0.896	1	20230503-P003	05/10/2023 13:59
7440-33-7	Tungsten	14.9		P1	2.24	4.48	1	20230503-P003	05/10/2023 13:59
7440-61-1	Uranium	22.4	U	P1	22.4	44.8	1	20230503-P003	05/10/2023 13:59
7440-62-2	Vanadium	1.43		P1	0.448	0.896	1	20230503-P003	05/10/2023 13:59
7440-65-5	Yttrium	0.448	U	P1	0.448	0.896	1	20230503-P003	05/10/2023 13:59
7440-66-6	Zinc	0.672	U	P1	0.672	1.34	1	20230503-P003	05/10/2023 13:59
7440-67-7	Zirconium	1.34	U	P1	1.34	2.69	1	20230503-P003	05/10/2023 13:59

Data Reporting Qualifiers (Qual)	***Columns***	***Instruments/Methods (M)***
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	MS2 - ICP-MS PE NexION/SW-846 Method 6020B
X - Analytical spike criteria was not met	M - Instrument	NA - Not Applicable
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI147-L-11

Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230424-6
Lab ID: 704602
Result Units: mg/Kg

SDG: 704601
SRR: 69508
Matrix: Aqueous
% Solids: NA

Case: 600825
Project: 27927.03.001
Receipt Date: 04/24/2023
Collection Date: NA

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	3,190	D	P1	88.5	177	10	20230503-P003	05/10/2023 12:14
7440-36-0	Antimony	2.21	U	P1	2.21	4.42	1	20230503-P003	05/10/2023 14:15
7440-38-2	Arsenic	2.21	U	P1	2.21	4.42	1	20230503-P003	05/10/2023 14:15
7440-39-3	Barium	0.442	U	P1	0.442	0.885	1	20230503-P003	05/10/2023 14:15
7440-41-7	Beryllium	0.442	U	P1	0.442	0.885	1	20230503-P003	05/10/2023 14:15
7440-69-9	Bismuth	3.54	U	P1	3.54	7.08	1	20230503-P003	05/10/2023 14:15
7440-42-8	Boron	11.5	J	P1	8.85	17.7	1	20230503-P003	05/10/2023 14:15
7440-43-9	Cadmium	0.442	U	P1	0.442	0.885	1	20230503-P003	05/10/2023 14:15
7440-70-2	Calcium	5.87	J	P1	4.42	8.85	1	20230503-P003	05/10/2023 14:15
7440-46-2	Cesium	0.442	UD	MS2	0.442	0.885	10	20230503-P003	05/11/2023 18:17
7440-47-3	Chromium	101		P1	0.442	0.885	1	20230503-P003	05/10/2023 14:15
7440-48-4	Cobalt	0.442	U	P1	0.442	0.885	1	20230503-P003	05/10/2023 14:15
7440-50-8	Copper	0.442	U	P1	0.442	0.885	1	20230503-P003	05/10/2023 14:15
7439-89-6	Iron	8.85	U	P1	8.85	17.7	1	20230503-P003	05/10/2023 14:15
7439-91-0	Lanthanum	1.33	U	P1	1.33	2.65	1	20230503-P003	05/10/2023 14:15
7439-92-1	Lead	1.02	J	P1	0.664	1.33	1	20230503-P003	05/10/2023 14:15
7439-93-2	Lithium	1.33	U	P3	1.33	2.65	1	20230503-P003	05/10/2023 15:18
7439-95-4	Magnesium	4.42	U	P1	4.42	8.85	1	20230503-P003	05/10/2023 14:15
7439-96-5	Manganese	0.442	U	P1	0.442	0.885	1	20230503-P003	05/10/2023 14:15
7439-98-7	Molybdenum	9.97		P1	0.885	1.77	1	20230503-P003	05/10/2023 14:15
7440-02-0	Nickel	1.25		P1	0.442	0.885	1	20230503-P003	05/10/2023 14:15
7440-05-3	Palladium	2.21	U	P1	2.21	4.42	1	20230503-P003	05/10/2023 14:15
7723-14-0	Phosphorus	2,400	D	P1	111	221	10	20230503-P003	05/10/2023 12:14
7440-09-7	Potassium	359		P3	13.3	26.5	1	20230503-P003	05/10/2023 15:18
7782-49-2	Selenium	2.21	U	P1	2.21	4.42	1	20230503-P003	05/10/2023 14:15
7440-21-3	Silicon	35.0		P1	11.1	22.1	1	20230503-P003	05/10/2023 14:15
7440-22-4	Silver	0.885	U	P1	0.885	1.77	1	20230503-P003	05/10/2023 14:15
7440-23-5	Sodium	59,500	D	P3	133	265	10	20230503-P003	05/10/2023 14:43
7440-24-6	Strontium	0.442	U	P1	0.442	0.885	1	20230503-P003	05/10/2023 14:15
7704-34-9	Sulfur	634	D	P1	66.4	133	10	20230503-P003	05/10/2023 12:14
7440-28-0	Thallium	6.64	U	P1	6.64	13.3	1	20230503-P003	05/10/2023 14:15
7440-29-1	Thorium	2.21	U	P1	2.21	4.42	1	20230503-P003	05/10/2023 14:15
7440-31-5	Tin	2.58	J	P1	1.77	3.54	1	20230503-P003	05/10/2023 14:15
7440-32-6	Titanium	0.442	U	P1	0.442	0.885	1	20230503-P003	05/10/2023 14:15
7440-33-7	Tungsten	16.2		P1	2.21	4.42	1	20230503-P003	05/10/2023 14:15
7440-61-1	Uranium	22.1	U	P1	22.1	44.2	1	20230503-P003	05/10/2023 14:15
7440-62-2	Vanadium	1.64		P1	0.442	0.885	1	20230503-P003	05/10/2023 14:15
7440-65-5	Yttrium	0.442	U	P1	0.442	0.885	1	20230503-P003	05/10/2023 14:15
7440-66-6	Zinc	0.664	U	P1	0.664	1.33	1	20230503-P003	05/10/2023 14:15
7440-67-7	Zirconium	1.33	U	P1	1.33	2.65	1	20230503-P003	05/10/2023 14:15

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	MS2 - ICP-MS PE NexION/SW-846 Method 6020B
X - Analytical spike criteria was not met	M - Instrument	NA - Not Applicable
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI147-L-13

Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230424-6
Lab ID: 704603
Result Units: mg/Kg

SDG: 704601
SRR: 69508
Matrix: Aqueous
% Solids: NA

Case: 600825
Project: 27927.03.001
Receipt Date: 04/24/2023
Collection Date: NA

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	3,180	D	P1	88.5	177	10	20230503-P003	05/10/2023 12:20
7440-36-0	Antimony	2.21	U	P1	2.21	4.43	1	20230503-P003	05/10/2023 14:21
7440-38-2	Arsenic	2.21	U	P1	2.21	4.43	1	20230503-P003	05/10/2023 14:21
7440-39-3	Barium	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 14:21
7440-41-7	Beryllium	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 14:21
7440-69-9	Bismuth	3.54	U	P1	3.54	7.08	1	20230503-P003	05/10/2023 14:21
7440-42-8	Boron	12.3	J	P1	8.85	17.7	1	20230503-P003	05/10/2023 14:21
7440-43-9	Cadmium	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 14:21
7440-70-2	Calcium	6.83	J	P1	4.43	8.85	1	20230503-P003	05/10/2023 14:21
7440-46-2	Cesium	0.443	UD	MS2	0.443	0.885	10	20230503-P003	05/11/2023 18:20
7440-47-3	Chromium	100		P1	0.443	0.885	1	20230503-P003	05/10/2023 14:21
7440-48-4	Cobalt	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 14:21
7440-50-8	Copper	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 14:21
7439-89-6	Iron	8.85	U	P1	8.85	17.7	1	20230503-P003	05/10/2023 14:21
7439-91-0	Lanthanum	1.33	U	P1	1.33	2.66	1	20230503-P003	05/10/2023 14:21
7439-92-1	Lead	0.968	J	P1	0.664	1.33	1	20230503-P003	05/10/2023 14:21
7439-93-2	Lithium	1.33	U	P3	1.33	2.66	1	20230503-P003	05/10/2023 15:24
7439-95-4	Magnesium	4.43	U	P1	4.43	8.85	1	20230503-P003	05/10/2023 14:21
7439-96-5	Manganese	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 14:21
7439-98-7	Molybdenum	9.92		P1	0.885	1.77	1	20230503-P003	05/10/2023 14:21
7440-02-0	Nickel	1.27		P1	0.443	0.885	1	20230503-P003	05/10/2023 14:21
7440-05-3	Palladium	2.21	U	P1	2.21	4.43	1	20230503-P003	05/10/2023 14:21
7723-14-0	Phosphorus	2,360	D	P1	111	221	10	20230503-P003	05/10/2023 12:20
7440-09-7	Potassium	357		P3	13.3	26.6	1	20230503-P003	05/10/2023 15:24
7782-49-2	Selenium	2.21	U	P1	2.21	4.43	1	20230503-P003	05/10/2023 14:21
7440-21-3	Silicon	44.5		P1	11.1	22.1	1	20230503-P003	05/10/2023 14:21
7440-22-4	Silver	0.885	U	P1	0.885	1.77	1	20230503-P003	05/10/2023 14:21
7440-23-5	Sodium	57,900	D	P3	133	266	10	20230503-P003	05/19/2023 16:29
7440-24-6	Strontium	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 14:21
7704-34-9	Sulfur	637	D	P1	66.4	133	10	20230503-P003	05/10/2023 12:20
7440-28-0	Thallium	6.64	U	P1	6.64	13.3	1	20230503-P003	05/10/2023 14:21
7440-29-1	Thorium	2.21	U	P1	2.21	4.43	1	20230503-P003	05/10/2023 14:21
7440-31-5	Tin	2.57	J	P1	1.77	3.54	1	20230503-P003	05/10/2023 14:21
7440-32-6	Titanium	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 14:21
7440-33-7	Tungsten	16.2		P1	2.21	4.43	1	20230503-P003	05/10/2023 14:21
7440-61-1	Uranium	22.1	U	P1	22.1	44.3	1	20230503-P003	05/10/2023 14:21
7440-62-2	Vanadium	1.54		P1	0.443	0.885	1	20230503-P003	05/10/2023 14:21
7440-65-5	Yttrium	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 14:21
7440-66-6	Zinc	0.664	U	P1	0.664	1.33	1	20230503-P003	05/10/2023 14:21
7440-67-7	Zirconium	1.33	U	P1	1.33	2.66	1	20230503-P003	05/10/2023 14:21

Data Reporting Qualifiers (Qual)	***Columns***	***Instruments/Methods (M)***
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	MS2 - ICP-MS PE NexION/SW-846 Method 6020B
X - Analytical spike criteria was not met	M - Instrument	NA - Not Applicable
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI147-L-15

Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230424-6
Lab ID: 704604
Result Units: mg/Kg

SDG: 704601
SRR: 69508
Matrix: Aqueous
% Solids: NA

Case: 600825
Project: 27927.03.001
Receipt Date: 04/24/2023
Collection Date: NA

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	3,210	D	P1	88.8	178	10	20230503-P003	05/10/2023 12:36
7440-36-0	Antimony	2.22	U	P1	2.22	4.44	1	20230503-P003	05/10/2023 14:26
7440-38-2	Arsenic	2.22	U	P1	2.22	4.44	1	20230503-P003	05/10/2023 14:26
7440-39-3	Barium	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 14:26
7440-41-7	Beryllium	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 14:26
7440-69-9	Bismuth	3.55	U	P1	3.55	7.10	1	20230503-P003	05/10/2023 14:26
7440-42-8	Boron	14.9	J	P1	8.88	17.8	1	20230503-P003	05/10/2023 14:26
7440-43-9	Cadmium	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 14:26
7440-70-2	Calcium	6.73	J	P1	4.44	8.88	1	20230503-P003	05/10/2023 14:26
7440-46-2	Cesium	0.444	UD	MS2	0.444	0.888	10	20230503-P003	05/11/2023 18:22
7440-47-3	Chromium	102		P1	0.444	0.888	1	20230503-P003	05/10/2023 14:26
7440-48-4	Cobalt	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 14:26
7440-50-8	Copper	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 14:26
7439-89-6	Iron	8.88	U	P1	8.88	17.8	1	20230503-P003	05/10/2023 14:26
7439-91-0	Lanthanum	1.33	U	P1	1.33	2.66	1	20230503-P003	05/10/2023 14:26
7439-92-1	Lead	0.776	J	P1	0.666	1.33	1	20230503-P003	05/10/2023 14:26
7439-93-2	Lithium	1.33	U	P3	1.33	2.66	1	20230503-P003	05/10/2023 15:25
7439-95-4	Magnesium	4.44	U	P1	4.44	8.88	1	20230503-P003	05/10/2023 14:26
7439-96-5	Manganese	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 14:26
7439-98-7	Molybdenum	10.1		P1	0.888	1.78	1	20230503-P003	05/10/2023 14:26
7440-02-0	Nickel	1.40		P1	0.444	0.888	1	20230503-P003	05/10/2023 14:26
7440-05-3	Palladium	2.22	U	P1	2.22	4.44	1	20230503-P003	05/10/2023 14:26
7723-14-0	Phosphorus	2,440	D	P1	111	222	10	20230503-P003	05/10/2023 12:36
7440-09-7	Potassium	362		P3	13.3	26.6	1	20230503-P003	05/10/2023 15:25
7782-49-2	Selenium	2.22	U	P1	2.22	4.44	1	20230503-P003	05/10/2023 14:26
7440-21-3	Silicon	45.4		P1	11.1	22.2	1	20230503-P003	05/10/2023 14:26
7440-22-4	Silver	0.888	U	P1	0.888	1.78	1	20230503-P003	05/10/2023 14:26
7440-23-5	Sodium	59,400	D	P3	133	266	10	20230503-P003	05/10/2023 14:53
7440-24-6	Strontium	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 14:26
7704-34-9	Sulfur	683	D	P1	66.6	133	10	20230503-P003	05/10/2023 12:36
7440-28-0	Thallium	6.66	U	P1	6.66	13.3	1	20230503-P003	05/10/2023 14:26
7440-29-1	Thorium	2.22	U	P1	2.22	4.44	1	20230503-P003	05/10/2023 14:26
7440-31-5	Tin	1.88	J	P1	1.78	3.55	1	20230503-P003	05/10/2023 14:26
7440-32-6	Titanium	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 14:26
7440-33-7	Tungsten	16.6		P1	2.22	4.44	1	20230503-P003	05/10/2023 14:26
7440-61-1	Uranium	22.2	U	P1	22.2	44.4	1	20230503-P003	05/10/2023 14:26
7440-62-2	Vanadium	1.58		P1	0.444	0.888	1	20230503-P003	05/10/2023 14:26
7440-65-5	Yttrium	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 14:26
7440-66-6	Zinc	0.666	U	P1	0.666	1.33	1	20230503-P003	05/10/2023 14:26
7440-67-7	Zirconium	1.33	U	P1	1.33	2.66	1	20230503-P003	05/10/2023 14:26

Data Reporting Qualifiers (Qual)	***Columns***	***Instruments/Methods (M)***
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	MS2 - ICP-MS PE NexION/SW-846 Method 6020B
X - Analytical spike criteria was not met	M - Instrument	NA - Not Applicable
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
T147-L-3

Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230424-6
Lab ID: 704605
Result Units: mg/Kg

SDG: 704601
SRR: 69508
Matrix: Aqueous
% Solids: NA

Case: 600825
Project: 27927.03.001
Receipt Date: 04/24/2023
Collection Date: NA

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	3,150	D	P1	88.5	177	10	20230503-P003	05/10/2023 12:42
7440-36-0	Antimony	2.21	U	P1	2.21	4.43	1	20230503-P003	05/10/2023 14:32
7440-38-2	Arsenic	2.21	U	P1	2.21	4.43	1	20230503-P003	05/10/2023 14:32
7440-39-3	Barium	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 14:32
7440-41-7	Beryllium	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 14:32
7440-69-9	Bismuth	3.54	U	P1	3.54	7.08	1	20230503-P003	05/10/2023 14:32
7440-42-8	Boron	8.85	U	P1	8.85	17.7	1	20230503-P003	05/10/2023 14:32
7440-43-9	Cadmium	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 14:32
7440-70-2	Calcium	5.45	J	P1	4.43	8.85	1	20230503-P003	05/10/2023 14:32
7440-46-2	Cesium	0.443	UD	MS2	0.443	0.885	10	20230503-P003	05/11/2023 18:27
7440-47-3	Chromium	98.1		P1	0.443	0.885	1	20230503-P003	05/10/2023 14:32
7440-48-4	Cobalt	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 14:32
7440-50-8	Copper	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 14:32
7439-89-6	Iron	8.85	U	P1	8.85	17.7	1	20230503-P003	05/10/2023 14:32
7439-91-0	Lanthanum	1.33	U	P1	1.33	2.66	1	20230503-P003	05/10/2023 14:32
7439-92-1	Lead	0.664	U	P1	0.664	1.33	1	20230503-P003	05/10/2023 14:32
7439-93-2	Lithium	1.33	U	P3	1.33	2.66	1	20230503-P003	05/10/2023 15:27
7439-95-4	Magnesium	4.43	U	P1	4.43	8.85	1	20230503-P003	05/10/2023 14:32
7439-96-5	Manganese	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 14:32
7439-98-7	Molybdenum	9.83		P1	0.885	1.77	1	20230503-P003	05/10/2023 14:32
7440-02-0	Nickel	1.20		P1	0.443	0.885	1	20230503-P003	05/10/2023 14:32
7440-05-3	Palladium	2.21	U	P1	2.21	4.43	1	20230503-P003	05/10/2023 14:32
7723-14-0	Phosphorus	2,280	D	P1	111	221	10	20230503-P003	05/10/2023 12:42
7440-09-7	Potassium	341		P3	13.3	26.6	1	20230503-P003	05/10/2023 15:27
7782-49-2	Selenium	2.21	U	P1	2.21	4.43	1	20230503-P003	05/10/2023 14:32
7440-21-3	Silicon	36.4		P1	11.1	22.1	1	20230503-P003	05/10/2023 14:32
7440-22-4	Silver	0.885	U	P1	0.885	1.77	1	20230503-P003	05/10/2023 14:32
7440-23-5	Sodium	57,500	D	P3	133	266	10	20230503-P003	05/10/2023 14:55
7440-24-6	Strontium	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 14:32
7704-34-9	Sulfur	621	D	P1	66.4	133	10	20230503-P003	05/10/2023 12:42
7440-28-0	Thallium	6.64	U	P1	6.64	13.3	1	20230503-P003	05/10/2023 14:32
7440-29-1	Thorium	2.21	U	P1	2.21	4.43	1	20230503-P003	05/10/2023 14:32
7440-31-5	Tin	2.46	J	P1	1.77	3.54	1	20230503-P003	05/10/2023 14:32
7440-32-6	Titanium	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 14:32
7440-33-7	Tungsten	15.2		P1	2.21	4.43	1	20230503-P003	05/10/2023 14:32
7440-61-1	Uranium	22.1	U	P1	22.1	44.3	1	20230503-P003	05/10/2023 14:32
7440-62-2	Vanadium	1.52		P1	0.443	0.885	1	20230503-P003	05/10/2023 14:32
7440-65-5	Yttrium	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 14:32
7440-66-6	Zinc	0.664	U	P1	0.664	1.33	1	20230503-P003	05/10/2023 14:32
7440-67-7	Zirconium	1.33	U	P1	1.33	2.66	1	20230503-P003	05/10/2023 14:32

Data Reporting Qualifiers (Qual)	***Columns***	***Instruments/Methods (M)***
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	MS2 - ICP-MS PE NexION/SW-846 Method 6020B
X - Analytical spike criteria was not met	M - Instrument	NA - Not Applicable
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form I
Certificate of Analysis

Client Sample ID
TI147-L-5
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230424-6
Lab ID: 704606
Result Units: mg/Kg

SDG: 704601
SRR: 69508
Matrix: Aqueous
% Solids: NA

Case: 600825
Project: 27927.03.001
Receipt Date: 04/24/2023
Collection Date: NA

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	3,280	D	P1	88.2	176	10	20230503-P003	05/10/2023 12:47
7440-36-0	Antimony	2.21	U	P1	2.21	4.41	1	20230503-P003	05/10/2023 14:37
7440-38-2	Arsenic	2.21	U	P1	2.21	4.41	1	20230503-P003	05/10/2023 14:37
7440-39-3	Barium	0.441	U	P1	0.441	0.882	1	20230503-P003	05/10/2023 14:37
7440-41-7	Beryllium	0.441	U	P1	0.441	0.882	1	20230503-P003	05/10/2023 14:37
7440-69-9	Bismuth	3.53	U	P1	3.53	7.06	1	20230503-P003	05/10/2023 14:37
7440-42-8	Boron	11.0	J	P1	8.82	17.6	1	20230503-P003	05/10/2023 14:37
7440-43-9	Cadmium	0.441	U	P1	0.441	0.882	1	20230503-P003	05/10/2023 14:37
7440-70-2	Calcium	6.44	J	P1	4.41	8.82	1	20230503-P003	05/10/2023 14:37
7440-46-2	Cesium	0.441	UD	MS2	0.441	0.882	10	20230503-P003	05/11/2023 18:37
7440-47-3	Chromium	103		P1	0.441	0.882	1	20230503-P003	05/10/2023 14:37
7440-48-4	Cobalt	0.441	U	P1	0.441	0.882	1	20230503-P003	05/10/2023 14:37
7440-50-8	Copper	0.441	U	P1	0.441	0.882	1	20230503-P003	05/10/2023 14:37
7439-89-6	Iron	8.82	U	P1	8.82	17.6	1	20230503-P003	05/10/2023 14:37
7439-91-0	Lanthanum	1.32	U	P1	1.32	2.65	1	20230503-P003	05/10/2023 14:37
7439-92-1	Lead	0.697	J	P1	0.662	1.32	1	20230503-P003	05/10/2023 14:37
7439-93-2	Lithium	1.32	U	P3	1.32	2.65	1	20230503-P003	05/10/2023 15:29
7439-95-4	Magnesium	4.41	U	P1	4.41	8.82	1	20230503-P003	05/10/2023 14:37
7439-96-5	Manganese	0.441	U	P1	0.441	0.882	1	20230503-P003	05/10/2023 14:37
7439-98-7	Molybdenum	10.3		P1	0.882	1.76	1	20230503-P003	05/10/2023 14:37
7440-02-0	Nickel	1.32		P1	0.441	0.882	1	20230503-P003	05/10/2023 14:37
7440-05-3	Palladium	2.21	U	P1	2.21	4.41	1	20230503-P003	05/10/2023 14:37
7723-14-0	Phosphorus	2,450	D	P1	110	221	10	20230503-P003	05/10/2023 12:47
7440-09-7	Potassium	350		P3	13.2	26.5	1	20230503-P003	05/10/2023 15:29
7782-49-2	Selenium	2.21	U	P1	2.21	4.41	1	20230503-P003	05/10/2023 14:37
7440-21-3	Silicon	40.0		P1	11.0	22.1	1	20230503-P003	05/10/2023 14:37
7440-22-4	Silver	0.882	U	P1	0.882	1.76	1	20230503-P003	05/10/2023 14:37
7440-23-5	Sodium	60,300	D	P3	132	265	10	20230503-P003	05/10/2023 14:56
7440-24-6	Strontium	0.441	U	P1	0.441	0.882	1	20230503-P003	05/10/2023 14:37
7704-34-9	Sulfur	658	D	P1	66.2	132	10	20230503-P003	05/10/2023 12:47
7440-28-0	Thallium	6.62	U	P1	6.62	13.2	1	20230503-P003	05/10/2023 14:37
7440-29-1	Thorium	2.21	U	P1	2.21	4.41	1	20230503-P003	05/10/2023 14:37
7440-31-5	Tin	2.59	J	P1	1.76	3.53	1	20230503-P003	05/10/2023 14:37
7440-32-6	Titanium	0.441	U	P1	0.441	0.882	1	20230503-P003	05/10/2023 14:37
7440-33-7	Tungsten	17.3		P1	2.21	4.41	1	20230503-P003	05/10/2023 14:37
7440-61-1	Uranium	22.1	U	P1	22.1	44.1	1	20230503-P003	05/10/2023 14:37
7440-62-2	Vanadium	1.66		P1	0.441	0.882	1	20230503-P003	05/10/2023 14:37
7440-65-5	Yttrium	0.441	U	P1	0.441	0.882	1	20230503-P003	05/10/2023 14:37
7440-66-6	Zinc	0.662	U	P1	0.662	1.32	1	20230503-P003	05/10/2023 14:37
7440-67-7	Zirconium	1.32	U	P1	1.32	2.65	1	20230503-P003	05/10/2023 14:37

Data Reporting Qualifiers (Qual)	***Columns***	***Instruments/Methods (M)***
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	MS2 - ICP-MS PE NexION/SW-846 Method 6020B
X - Analytical spike criteria was not met	M - Instrument	NA - Not Applicable
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
T147-L-7

Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230424-6
Lab ID: 704607
Result Units: mg/Kg

SDG: 704601
SRR: 69508
Matrix: Aqueous
% Solids: NA

Case: 600825
Project: 27927.03.001
Receipt Date: 04/24/2023
Collection Date: NA

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	3,200	D	P1	88.0	176	10	20230503-P003	05/10/2023 12:53
7440-36-0	Antimony	2.20	U	P1	2.20	4.40	1	20230503-P003	05/10/2023 14:43
7440-38-2	Arsenic	2.20	U	P1	2.20	4.40	1	20230503-P003	05/10/2023 14:43
7440-39-3	Barium	0.440	U	P1	0.440	0.880	1	20230503-P003	05/10/2023 14:43
7440-41-7	Beryllium	0.440	U	P1	0.440	0.880	1	20230503-P003	05/10/2023 14:43
7440-69-9	Bismuth	3.52	U	P1	3.52	7.04	1	20230503-P003	05/10/2023 14:43
7440-42-8	Boron	18.8		P1	8.80	17.6	1	20230503-P003	05/10/2023 14:43
7440-43-9	Cadmium	0.440	U	P1	0.440	0.880	1	20230503-P003	05/10/2023 14:43
7440-70-2	Calcium	7.75	J	P1	4.40	8.80	1	20230503-P003	05/10/2023 14:43
7440-46-2	Cesium	1.12	D	MS2	0.440	0.880	10	20230503-P003	05/11/2023 18:40
7440-47-3	Chromium	102		P1	0.440	0.880	1	20230503-P003	05/10/2023 14:43
7440-48-4	Cobalt	0.440	U	P1	0.440	0.880	1	20230503-P003	05/10/2023 14:43
7440-50-8	Copper	0.440	U	P1	0.440	0.880	1	20230503-P003	05/10/2023 14:43
7439-89-6	Iron	8.80	U	P1	8.80	17.6	1	20230503-P003	05/10/2023 14:43
7439-91-0	Lanthanum	1.32	U	P1	1.32	2.64	1	20230503-P003	05/10/2023 14:43
7439-92-1	Lead	1.50		P1	0.660	1.32	1	20230503-P003	05/10/2023 14:43
7439-93-2	Lithium	1.32	U	P3	1.32	2.64	1	20230503-P003	05/10/2023 15:31
7439-95-4	Magnesium	4.40	U	P1	4.40	8.80	1	20230503-P003	05/10/2023 14:43
7439-96-5	Manganese	0.440	U	P1	0.440	0.880	1	20230503-P003	05/10/2023 14:43
7439-98-7	Molybdenum	10.1		P1	0.880	1.76	1	20230503-P003	05/10/2023 14:43
7440-02-0	Nickel	1.35		P1	0.440	0.880	1	20230503-P003	05/10/2023 14:43
7440-05-3	Palladium	2.20	U	P1	2.20	4.40	1	20230503-P003	05/10/2023 14:43
7723-14-0	Phosphorus	2,460	D	P1	110	220	10	20230503-P003	05/10/2023 12:53
7440-09-7	Potassium	344		P3	13.2	26.4	1	20230503-P003	05/10/2023 15:31
7782-49-2	Selenium	2.20	U	P1	2.20	4.40	1	20230503-P003	05/10/2023 14:43
7440-21-3	Silicon	65.8		P1	11.0	22.0	1	20230503-P003	05/10/2023 14:43
7440-22-4	Silver	0.880	U	P1	0.880	1.76	1	20230503-P003	05/10/2023 14:43
7440-23-5	Sodium	59,200	D	P3	132	264	10	20230503-P003	05/10/2023 14:58
7440-24-6	Strontium	0.440	U	P1	0.440	0.880	1	20230503-P003	05/10/2023 14:43
7704-34-9	Sulfur	661	D	P1	66.0	132	10	20230503-P003	05/10/2023 12:53
7440-28-0	Thallium	6.60	U	P1	6.60	13.2	1	20230503-P003	05/10/2023 14:43
7440-29-1	Thorium	2.20	U	P1	2.20	4.40	1	20230503-P003	05/10/2023 14:43
7440-31-5	Tin	2.48	J	P1	1.76	3.52	1	20230503-P003	05/10/2023 14:43
7440-32-6	Titanium	0.440	U	P1	0.440	0.880	1	20230503-P003	05/10/2023 14:43
7440-33-7	Tungsten	16.7		P1	2.20	4.40	1	20230503-P003	05/10/2023 14:43
7440-61-1	Uranium	22.0	U	P1	22.0	44.0	1	20230503-P003	05/10/2023 14:43
7440-62-2	Vanadium	1.60		P1	0.440	0.880	1	20230503-P003	05/10/2023 14:43
7440-65-5	Yttrium	0.440	U	P1	0.440	0.880	1	20230503-P003	05/10/2023 14:43
7440-66-6	Zinc	0.660	U	P1	0.660	1.32	1	20230503-P003	05/10/2023 14:43
7440-67-7	Zirconium	1.32	U	P1	1.32	2.64	1	20230503-P003	05/10/2023 14:43

Data Reporting Qualifiers (Qual)	***Columns***	***Instruments/Methods (M)***
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	MS2 - ICP-MS PE NexION/SW-846 Method 6020B
X - Analytical spike criteria was not met	M - Instrument	NA - Not Applicable
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
T147-L-9
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230424-6
Lab ID: 704608
Result Units: mg/Kg

SDG: 704601
SRR: 69508
Matrix: Aqueous
% Solids: NA

Case: 600825
Project: 27927.03.001
Receipt Date: 04/24/2023
Collection Date: NA

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	3,180	D	P1	88.2	176	10	20230503-P003	05/10/2023 12:58
7440-36-0	Antimony	2.21	U	P1	2.21	4.41	1	20230503-P003	05/10/2023 14:48
7440-38-2	Arsenic	2.21	U	P1	2.21	4.41	1	20230503-P003	05/10/2023 14:48
7440-39-3	Barium	0.441	U	P1	0.441	0.882	1	20230503-P003	05/10/2023 14:48
7440-41-7	Beryllium	0.441	U	P1	0.441	0.882	1	20230503-P003	05/10/2023 14:48
7440-69-9	Bismuth	3.53	U	P1	3.53	7.06	1	20230503-P003	05/10/2023 14:48
7440-42-8	Boron	9.63	J	P1	8.82	17.6	1	20230503-P003	05/10/2023 14:48
7440-43-9	Cadmium	0.441	U	P1	0.441	0.882	1	20230503-P003	05/10/2023 14:48
7440-70-2	Calcium	6.15	J	P1	4.41	8.82	1	20230503-P003	05/10/2023 14:48
7440-46-2	Cesium	0.441	UD	MS2	0.441	0.882	10	20230503-P003	05/11/2023 18:42
7440-47-3	Chromium	102		P1	0.441	0.882	1	20230503-P003	05/10/2023 14:48
7440-48-4	Cobalt	0.441	U	P1	0.441	0.882	1	20230503-P003	05/10/2023 14:48
7440-50-8	Copper	0.441	U	P1	0.441	0.882	1	20230503-P003	05/10/2023 14:48
7439-89-6	Iron	8.82	U	P1	8.82	17.6	1	20230503-P003	05/10/2023 14:48
7439-91-0	Lanthanum	1.32	U	P1	1.32	2.65	1	20230503-P003	05/10/2023 14:48
7439-92-1	Lead	0.930	J	P1	0.662	1.32	1	20230503-P003	05/10/2023 14:48
7439-93-2	Lithium	1.32	U	P3	1.32	2.65	1	20230503-P003	05/10/2023 15:33
7439-95-4	Magnesium	4.41	U	P1	4.41	8.82	1	20230503-P003	05/10/2023 14:48
7439-96-5	Manganese	0.441	U	P1	0.441	0.882	1	20230503-P003	05/10/2023 14:48
7439-98-7	Molybdenum	10.3		P1	0.882	1.76	1	20230503-P003	05/10/2023 14:48
7440-02-0	Nickel	1.25		P1	0.441	0.882	1	20230503-P003	05/10/2023 14:48
7440-05-3	Palladium	2.21	U	P1	2.21	4.41	1	20230503-P003	05/10/2023 14:48
7723-14-0	Phosphorus	2,370	D	P1	110	221	10	20230503-P003	05/10/2023 12:58
7440-09-7	Potassium	344		P3	13.2	26.5	1	20230503-P003	05/10/2023 15:33
7782-49-2	Selenium	2.21	U	P1	2.21	4.41	1	20230503-P003	05/10/2023 14:48
7440-21-3	Silicon	38.2		P1	11.0	22.1	1	20230503-P003	05/10/2023 14:48
7440-22-4	Silver	0.882	U	P1	0.882	1.76	1	20230503-P003	05/10/2023 14:48
7440-23-5	Sodium	58,900	D	P3	132	265	10	20230503-P003	05/10/2023 14:59
7440-24-6	Strontium	0.441	U	P1	0.441	0.882	1	20230503-P003	05/10/2023 14:48
7704-34-9	Sulfur	636	D	P1	66.2	132	10	20230503-P003	05/10/2023 12:58
7440-28-0	Thallium	6.62	U	P1	6.62	13.2	1	20230503-P003	05/10/2023 14:48
7440-29-1	Thorium	2.21	U	P1	2.21	4.41	1	20230503-P003	05/10/2023 14:48
7440-31-5	Tin	2.32	J	P1	1.76	3.53	1	20230503-P003	05/10/2023 14:48
7440-32-6	Titanium	0.441	U	P1	0.441	0.882	1	20230503-P003	05/10/2023 14:48
7440-33-7	Tungsten	16.8		P1	2.21	4.41	1	20230503-P003	05/10/2023 14:48
7440-61-1	Uranium	22.1	U	P1	22.1	44.1	1	20230503-P003	05/10/2023 14:48
7440-62-2	Vanadium	1.56		P1	0.441	0.882	1	20230503-P003	05/10/2023 14:48
7440-65-5	Yttrium	0.441	U	P1	0.441	0.882	1	20230503-P003	05/10/2023 14:48
7440-66-6	Zinc	0.662	U	P1	0.662	1.32	1	20230503-P003	05/10/2023 14:48
7440-67-7	Zirconium	1.32	U	P1	1.32	2.65	1	20230503-P003	05/10/2023 14:48

Data Reporting Qualifiers (Qual)	***Columns***	***Instruments/Methods (M)***
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	MS2 - ICP-MS PE NexION/SW-846 Method 6020B
X - Analytical spike criteria was not met	M - Instrument	NA - Not Applicable
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI147-P-1

Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230424-6
Lab ID: 704609
Result Units: mg/Kg

SDG: 704601
SRR: 69508
Matrix: Aqueous
% Solids: NA

Case: 600825
Project: 27927.03.001
Receipt Date: 04/24/2023
Collection Date: NA

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	2,920	D	P1	88.8	178	10	20230503-P003	05/10/2023 13:04
7440-36-0	Antimony	2.22	U	P1	2.22	4.44	1	20230503-P003	05/10/2023 15:05
7440-38-2	Arsenic	2.22	U	P1	2.22	4.44	1	20230503-P003	05/10/2023 15:05
7440-39-3	Barium	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:05
7440-41-7	Beryllium	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:05
7440-69-9	Bismuth	3.55	U	P1	3.55	7.11	1	20230503-P003	05/10/2023 15:05
7440-42-8	Boron	21.1		P1	8.88	17.8	1	20230503-P003	05/10/2023 15:05
7440-43-9	Cadmium	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:05
7440-70-2	Calcium	5.60	J	P1	4.44	8.88	1	20230503-P003	05/10/2023 15:05
7440-46-2	Cesium	0.444	UD	MS2	0.444	0.888	10	20230503-P003	05/11/2023 18:45
7440-47-3	Chromium	93.4		P1	0.444	0.888	1	20230503-P003	05/10/2023 15:05
7440-48-4	Cobalt	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:05
7440-50-8	Copper	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:05
7439-89-6	Iron	8.88	U	P1	8.88	17.8	1	20230503-P003	05/10/2023 15:05
7439-91-0	Lanthanum	1.33	U	P1	1.33	2.66	1	20230503-P003	05/10/2023 15:05
7439-92-1	Lead	0.666	U	P1	0.666	1.33	1	20230503-P003	05/10/2023 15:05
7439-93-2	Lithium	1.33	U	P3	1.33	2.66	1	20230503-P003	05/10/2023 15:38
7439-95-4	Magnesium	4.44	U	P1	4.44	8.88	1	20230503-P003	05/10/2023 15:05
7439-96-5	Manganese	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:05
7439-98-7	Molybdenum	9.28		P1	0.888	1.78	1	20230503-P003	05/10/2023 15:05
7440-02-0	Nickel	1.21		P1	0.444	0.888	1	20230503-P003	05/10/2023 15:05
7440-05-3	Palladium	2.22	U	P1	2.22	4.44	1	20230503-P003	05/10/2023 15:05
7723-14-0	Phosphorus	2,230	D	P1	111	222	10	20230503-P003	05/10/2023 13:04
7440-09-7	Potassium	275		P3	13.3	26.6	1	20230503-P003	05/10/2023 15:38
7782-49-2	Selenium	2.22	U	P1	2.22	4.44	1	20230503-P003	05/10/2023 15:05
7440-21-3	Silicon	72.6		P1	11.1	22.2	1	20230503-P003	05/10/2023 15:05
7440-22-4	Silver	0.888	U	P1	0.888	1.78	1	20230503-P003	05/10/2023 15:05
7440-23-5	Sodium	55,000	D	P3	133	266	10	20230503-P003	05/10/2023 15:01
7440-24-6	Strontium	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:05
7704-34-9	Sulfur	618	D	P1	66.6	133	10	20230503-P003	05/10/2023 13:04
7440-28-0	Thallium	6.66	U	P1	6.66	13.3	1	20230503-P003	05/10/2023 15:05
7440-29-1	Thorium	2.22	U	P1	2.22	4.44	1	20230503-P003	05/10/2023 15:05
7440-31-5	Tin	1.87	J	P1	1.78	3.55	1	20230503-P003	05/10/2023 15:05
7440-32-6	Titanium	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:05
7440-33-7	Tungsten	15.6		P1	2.22	4.44	1	20230503-P003	05/10/2023 15:05
7440-61-1	Uranium	22.2	U	P1	22.2	44.4	1	20230503-P003	05/10/2023 15:05
7440-62-2	Vanadium	1.43		P1	0.444	0.888	1	20230503-P003	05/10/2023 15:05
7440-65-5	Yttrium	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:05
7440-66-6	Zinc	0.666	U	P1	0.666	1.33	1	20230503-P003	05/10/2023 15:05
7440-67-7	Zirconium	1.33	U	P1	1.33	2.66	1	20230503-P003	05/10/2023 15:05

Data Reporting Qualifiers (Qual)	***Columns***	***Instruments/Methods (M)***
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	MS2 - ICP-MS PE NexION/SW-846 Method 6020B
X - Analytical spike criteria was not met	M - Instrument	NA - Not Applicable
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI147-P-11

Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230424-6
Lab ID: 704610
Result Units: mg/Kg

SDG: 704601
SRR: 69508
Matrix: Aqueous
% Solids: NA

Case: 600825
Project: 27927.03.001
Receipt Date: 04/24/2023
Collection Date: NA

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	3,170	D	P1	88.5	177	10	20230503-P003	05/10/2023 13:09
7440-36-0	Antimony	2.21	U	P1	2.21	4.43	1	20230503-P003	05/10/2023 15:10
7440-38-2	Arsenic	2.21	U	P1	2.21	4.43	1	20230503-P003	05/10/2023 15:10
7440-39-3	Barium	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 15:10
7440-41-7	Beryllium	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 15:10
7440-69-9	Bismuth	3.54	U	P1	3.54	7.08	1	20230503-P003	05/10/2023 15:10
7440-42-8	Boron	10.9	J	P1	8.85	17.7	1	20230503-P003	05/10/2023 15:10
7440-43-9	Cadmium	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 15:10
7440-70-2	Calcium	6.61	J	P1	4.43	8.85	1	20230503-P003	05/10/2023 15:10
7440-46-2	Cesium	0.443	UD	MS2	0.443	0.885	10	20230503-P003	05/11/2023 18:47
7440-47-3	Chromium	101		P1	0.443	0.885	1	20230503-P003	05/10/2023 15:10
7440-48-4	Cobalt	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 15:10
7440-50-8	Copper	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 15:10
7439-89-6	Iron	8.85	U	P1	8.85	17.7	1	20230503-P003	05/10/2023 15:10
7439-91-0	Lanthanum	1.33	U	P1	1.33	2.66	1	20230503-P003	05/10/2023 15:10
7439-92-1	Lead	1.17	J	P1	0.664	1.33	1	20230503-P003	05/10/2023 15:10
7439-93-2	Lithium	1.33	U	P3	1.33	2.66	1	20230503-P003	05/10/2023 15:40
7439-95-4	Magnesium	4.43	U	P1	4.43	8.85	1	20230503-P003	05/10/2023 15:10
7439-96-5	Manganese	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 15:10
7439-98-7	Molybdenum	10.2		P1	0.885	1.77	1	20230503-P003	05/10/2023 15:10
7440-02-0	Nickel	1.38		P1	0.443	0.885	1	20230503-P003	05/10/2023 15:10
7440-05-3	Palladium	2.21	U	P1	2.21	4.43	1	20230503-P003	05/10/2023 15:10
7723-14-0	Phosphorus	2,390	D	P1	111	221	10	20230503-P003	05/10/2023 13:09
7440-09-7	Potassium	342		P3	13.3	26.6	1	20230503-P003	05/10/2023 15:40
7782-49-2	Selenium	2.21	U	P1	2.21	4.43	1	20230503-P003	05/10/2023 15:10
7440-21-3	Silicon	34.9		P1	11.1	22.1	1	20230503-P003	05/10/2023 15:10
7440-22-4	Silver	0.885	U	P1	0.885	1.77	1	20230503-P003	05/10/2023 15:10
7440-23-5	Sodium	59,300	D	P3	133	266	10	20230503-P003	05/10/2023 15:02
7440-24-6	Strontium	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 15:10
7704-34-9	Sulfur	655	D	P1	66.4	133	10	20230503-P003	05/10/2023 13:09
7440-28-0	Thallium	6.64	U	P1	6.64	13.3	1	20230503-P003	05/10/2023 15:10
7440-29-1	Thorium	2.21	U	P1	2.21	4.43	1	20230503-P003	05/10/2023 15:10
7440-31-5	Tin	2.07	J	P1	1.77	3.54	1	20230503-P003	05/10/2023 15:10
7440-32-6	Titanium	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 15:10
7440-33-7	Tungsten	16.6		P1	2.21	4.43	1	20230503-P003	05/10/2023 15:10
7440-61-1	Uranium	22.1	U	P1	22.1	44.3	1	20230503-P003	05/10/2023 15:10
7440-62-2	Vanadium	1.66		P1	0.443	0.885	1	20230503-P003	05/10/2023 15:10
7440-65-5	Yttrium	0.443	U	P1	0.443	0.885	1	20230503-P003	05/10/2023 15:10
7440-66-6	Zinc	0.664	U	P1	0.664	1.33	1	20230503-P003	05/10/2023 15:10
7440-67-7	Zirconium	1.33	U	P1	1.33	2.66	1	20230503-P003	05/10/2023 15:10

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	MS2 - ICP-MS PE NexION/SW-846 Method 6020B
X - Analytical spike criteria was not met	M - Instrument	NA - Not Applicable
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI147-P-3
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230424-6
Lab ID: 704611
Result Units: mg/Kg

SDG: 704601
SRR: 69508
Matrix: Aqueous
% Solids: NA

Case: 600825
Project: 27927.03.001
Receipt Date: 04/24/2023
Collection Date: NA

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	3,200	D	P1	88.6	177	10	20230503-P003	05/10/2023 13:15
7440-36-0	Antimony	2.21	U	P1	2.21	4.43	1	20230503-P003	05/10/2023 15:16
7440-38-2	Arsenic	2.21	U	P1	2.21	4.43	1	20230503-P003	05/10/2023 15:16
7440-39-3	Barium	0.443	U	P1	0.443	0.886	1	20230503-P003	05/10/2023 15:16
7440-41-7	Beryllium	0.443	U	P1	0.443	0.886	1	20230503-P003	05/10/2023 15:16
7440-69-9	Bismuth	3.54	U	P1	3.54	7.08	1	20230503-P003	05/10/2023 15:16
7440-42-8	Boron	8.86	U	P1	8.86	17.7	1	20230503-P003	05/10/2023 15:16
7440-43-9	Cadmium	0.443	U	P1	0.443	0.886	1	20230503-P003	05/10/2023 15:16
7440-70-2	Calcium	5.85	J	P1	4.43	8.86	1	20230503-P003	05/10/2023 15:16
7440-46-2	Cesium	0.443	UD	MS2	0.443	0.886	10	20230503-P003	05/11/2023 18:50
7440-47-3	Chromium	99.6		P1	0.443	0.886	1	20230503-P003	05/10/2023 15:16
7440-48-4	Cobalt	0.443	U	P1	0.443	0.886	1	20230503-P003	05/10/2023 15:16
7440-50-8	Copper	0.443	U	P1	0.443	0.886	1	20230503-P003	05/10/2023 15:16
7439-89-6	Iron	8.86	U	P1	8.86	17.7	1	20230503-P003	05/10/2023 15:16
7439-91-0	Lanthanum	1.33	U	P1	1.33	2.66	1	20230503-P003	05/10/2023 15:16
7439-92-1	Lead	0.786	J	P1	0.664	1.33	1	20230503-P003	05/10/2023 15:16
7439-93-2	Lithium	1.33	U	P3	1.33	2.66	1	20230503-P003	05/10/2023 15:42
7439-95-4	Magnesium	4.43	U	P1	4.43	8.86	1	20230503-P003	05/10/2023 15:16
7439-96-5	Manganese	0.443	U	P1	0.443	0.886	1	20230503-P003	05/10/2023 15:16
7439-98-7	Molybdenum	10.1		P1	0.886	1.77	1	20230503-P003	05/10/2023 15:16
7440-02-0	Nickel	1.23		P1	0.443	0.886	1	20230503-P003	05/10/2023 15:16
7440-05-3	Palladium	2.21	U	P1	2.21	4.43	1	20230503-P003	05/10/2023 15:16
7723-14-0	Phosphorus	2,340	D	P1	111	221	10	20230503-P003	05/10/2023 13:15
7440-09-7	Potassium	333		P3	13.3	26.6	1	20230503-P003	05/10/2023 15:42
7782-49-2	Selenium	2.21	U	P1	2.21	4.43	1	20230503-P003	05/10/2023 15:16
7440-21-3	Silicon	37.3		P1	11.1	22.1	1	20230503-P003	05/10/2023 15:16
7440-22-4	Silver	0.886	U	P1	0.886	1.77	1	20230503-P003	05/10/2023 15:16
7440-23-5	Sodium	58,900	D	P3	133	266	10	20230503-P003	05/10/2023 15:04
7440-24-6	Strontium	0.443	U	P1	0.443	0.886	1	20230503-P003	05/10/2023 15:16
7704-34-9	Sulfur	657	D	P1	66.4	133	10	20230503-P003	05/10/2023 13:15
7440-28-0	Thallium	6.64	U	P1	6.64	13.3	1	20230503-P003	05/10/2023 15:16
7440-29-1	Thorium	2.21	U	P1	2.21	4.43	1	20230503-P003	05/10/2023 15:16
7440-31-5	Tin	2.40	J	P1	1.77	3.54	1	20230503-P003	05/10/2023 15:16
7440-32-6	Titanium	0.443	U	P1	0.443	0.886	1	20230503-P003	05/10/2023 15:16
7440-33-7	Tungsten	16.8		P1	2.21	4.43	1	20230503-P003	05/10/2023 15:16
7440-61-1	Uranium	22.1	U	P1	22.1	44.3	1	20230503-P003	05/10/2023 15:16
7440-62-2	Vanadium	1.55		P1	0.443	0.886	1	20230503-P003	05/10/2023 15:16
7440-65-5	Yttrium	0.443	U	P1	0.443	0.886	1	20230503-P003	05/10/2023 15:16
7440-66-6	Zinc	0.664	U	P1	0.664	1.33	1	20230503-P003	05/10/2023 15:16
7440-67-7	Zirconium	1.33	U	P1	1.33	2.66	1	20230503-P003	05/10/2023 15:16

Data Reporting Qualifiers (Qual)	***Columns***	***Instruments/Methods (M)***
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	MS2 - ICP-MS PE NexION/SW-846 Method 6020B
X - Analytical spike criteria was not met	M - Instrument	NA - Not Applicable
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI147-P-5
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230424-6
Lab ID: 704612
Result Units: mg/Kg

SDG: 704601
SRR: 69508
Matrix: Aqueous
% Solids: NA

Case: 600825
Project: 27927.03.001
Receipt Date: 04/24/2023
Collection Date: NA

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	3,160	D	P1	88.8	178	10	20230503-P003	05/10/2023 13:20
7440-36-0	Antimony	2.22	U	P1	2.22	4.44	1	20230503-P003	05/10/2023 15:21
7440-38-2	Arsenic	2.22	U	P1	2.22	4.44	1	20230503-P003	05/10/2023 15:21
7440-39-3	Barium	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:21
7440-41-7	Beryllium	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:21
7440-69-9	Bismuth	3.55	U	P1	3.55	7.11	1	20230503-P003	05/10/2023 15:21
7440-42-8	Boron	9.77	J	P1	8.88	17.8	1	20230503-P003	05/10/2023 15:21
7440-43-9	Cadmium	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:21
7440-70-2	Calcium	5.70	J	P1	4.44	8.88	1	20230503-P003	05/10/2023 15:21
7440-46-2	Cesium	0.444	UD	MS2	0.444	0.888	10	20230503-P003	05/11/2023 18:52
7440-47-3	Chromium	99.8		P1	0.444	0.888	1	20230503-P003	05/10/2023 15:21
7440-48-4	Cobalt	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:21
7440-50-8	Copper	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:21
7439-89-6	Iron	8.88	U	P1	8.88	17.8	1	20230503-P003	05/10/2023 15:21
7439-91-0	Lanthanum	1.33	U	P1	1.33	2.67	1	20230503-P003	05/10/2023 15:21
7439-92-1	Lead	0.756	J	P1	0.666	1.33	1	20230503-P003	05/10/2023 15:21
7439-93-2	Lithium	1.33	U	P3	1.33	2.67	1	20230503-P003	05/10/2023 15:43
7439-95-4	Magnesium	4.44	U	P1	4.44	8.88	1	20230503-P003	05/10/2023 15:21
7439-96-5	Manganese	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:21
7439-98-7	Molybdenum	9.89		P1	0.888	1.78	1	20230503-P003	05/10/2023 15:21
7440-02-0	Nickel	1.27		P1	0.444	0.888	1	20230503-P003	05/10/2023 15:21
7440-05-3	Palladium	2.22	U	P1	2.22	4.44	1	20230503-P003	05/10/2023 15:21
7723-14-0	Phosphorus	2,290	D	P1	111	222	10	20230503-P003	05/10/2023 13:20
7440-09-7	Potassium	330		P3	13.3	26.7	1	20230503-P003	05/10/2023 15:43
7782-49-2	Selenium	2.22	U	P1	2.22	4.44	1	20230503-P003	05/10/2023 15:21
7440-21-3	Silicon	40.2		P1	11.1	22.2	1	20230503-P003	05/10/2023 15:21
7440-22-4	Silver	0.888	U	P1	0.888	1.78	1	20230503-P003	05/10/2023 15:21
7440-23-5	Sodium	58,600	D	P3	133	267	10	20230503-P003	05/10/2023 15:05
7440-24-6	Strontium	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:21
7704-34-9	Sulfur	620	D	P1	66.6	133	10	20230503-P003	05/10/2023 13:20
7440-28-0	Thallium	6.66	U	P1	6.66	13.3	1	20230503-P003	05/10/2023 15:21
7440-29-1	Thorium	2.22	U	P1	2.22	4.44	1	20230503-P003	05/10/2023 15:21
7440-31-5	Tin	2.26	J	P1	1.78	3.55	1	20230503-P003	05/10/2023 15:21
7440-32-6	Titanium	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:21
7440-33-7	Tungsten	16.9		P1	2.22	4.44	1	20230503-P003	05/10/2023 15:21
7440-61-1	Uranium	22.2	U	P1	22.2	44.4	1	20230503-P003	05/10/2023 15:21
7440-62-2	Vanadium	1.52		P1	0.444	0.888	1	20230503-P003	05/10/2023 15:21
7440-65-5	Yttrium	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:21
7440-66-6	Zinc	0.666	U	P1	0.666	1.33	1	20230503-P003	05/10/2023 15:21
7440-67-7	Zirconium	1.33	U	P1	1.33	2.67	1	20230503-P003	05/10/2023 15:21

Data Reporting Qualifiers (Qual)	***Columns***	***Instruments/Methods (M)***
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	MS2 - ICP-MS PE NexION/SW-846 Method 6020B
X - Analytical spike criteria was not met	M - Instrument	NA - Not Applicable
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI147-P-7
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230424-6
Lab ID: 704613
Result Units: mg/Kg

SDG: 704601
SRR: 69508
Matrix: Aqueous
% Solids: NA

Case: 600825
Project: 27927.03.001
Receipt Date: 04/24/2023
Collection Date: NA

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	3,170	D	P1	88.8	178	10	20230503-P003	05/10/2023 13:26
7440-36-0	Antimony	2.22	U	P1	2.22	4.44	1	20230503-P003	05/10/2023 15:27
7440-38-2	Arsenic	2.22	U	P1	2.22	4.44	1	20230503-P003	05/10/2023 15:27
7440-39-3	Barium	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:27
7440-41-7	Beryllium	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:27
7440-69-9	Bismuth	3.55	U	P1	3.55	7.10	1	20230503-P003	05/10/2023 15:27
7440-42-8	Boron	8.88	U	P1	8.88	17.8	1	20230503-P003	05/10/2023 15:27
7440-43-9	Cadmium	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:27
7440-70-2	Calcium	5.86	J	P1	4.44	8.88	1	20230503-P003	05/10/2023 15:27
7440-46-2	Cesium	0.444	UD	MS2	0.444	0.888	10	20230503-P003	05/11/2023 18:55
7440-47-3	Chromium	103		P1	0.444	0.888	1	20230503-P003	05/10/2023 15:27
7440-48-4	Cobalt	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:27
7440-50-8	Copper	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:27
7439-89-6	Iron	8.88	U	P1	8.88	17.8	1	20230503-P003	05/10/2023 15:27
7439-91-0	Lanthanum	1.33	U	P1	1.33	2.66	1	20230503-P003	05/10/2023 15:27
7439-92-1	Lead	0.719	J	P1	0.666	1.33	1	20230503-P003	05/10/2023 15:27
7439-93-2	Lithium	1.33	U	P3	1.33	2.66	1	20230503-P003	05/10/2023 15:45
7439-95-4	Magnesium	4.44	U	P1	4.44	8.88	1	20230503-P003	05/10/2023 15:27
7439-96-5	Manganese	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:27
7439-98-7	Molybdenum	10.3		P1	0.888	1.78	1	20230503-P003	05/10/2023 15:27
7440-02-0	Nickel	1.27		P1	0.444	0.888	1	20230503-P003	05/10/2023 15:27
7440-05-3	Palladium	2.22	U	P1	2.22	4.44	1	20230503-P003	05/10/2023 15:27
7723-14-0	Phosphorus	2,450	D	P1	111	222	10	20230503-P003	05/10/2023 13:26
7440-09-7	Potassium	334		P3	13.3	26.6	1	20230503-P003	05/10/2023 15:45
7782-49-2	Selenium	2.22	U	P1	2.22	4.44	1	20230503-P003	05/10/2023 15:27
7440-21-3	Silicon	34.5		P1	11.1	22.2	1	20230503-P003	05/10/2023 15:27
7440-22-4	Silver	0.888	U	P1	0.888	1.78	1	20230503-P003	05/10/2023 15:27
7440-23-5	Sodium	58,700	D	P3	133	266	10	20230503-P003	05/10/2023 15:07
7440-24-6	Strontium	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:27
7704-34-9	Sulfur	654	D	P1	66.6	133	10	20230503-P003	05/10/2023 13:26
7440-28-0	Thallium	6.66	U	P1	6.66	13.3	1	20230503-P003	05/10/2023 15:27
7440-29-1	Thorium	2.22	U	P1	2.22	4.44	1	20230503-P003	05/10/2023 15:27
7440-31-5	Tin	2.35	J	P1	1.78	3.55	1	20230503-P003	05/10/2023 15:27
7440-32-6	Titanium	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:27
7440-33-7	Tungsten	16.6		P1	2.22	4.44	1	20230503-P003	05/10/2023 15:27
7440-61-1	Uranium	22.2	U	P1	22.2	44.4	1	20230503-P003	05/10/2023 15:27
7440-62-2	Vanadium	1.62		P1	0.444	0.888	1	20230503-P003	05/10/2023 15:27
7440-65-5	Yttrium	0.444	U	P1	0.444	0.888	1	20230503-P003	05/10/2023 15:27
7440-66-6	Zinc	0.666	U	P1	0.666	1.33	1	20230503-P003	05/10/2023 15:27
7440-67-7	Zirconium	1.33	U	P1	1.33	2.66	1	20230503-P003	05/10/2023 15:27

Data Reporting Qualifiers (Qual)	***Columns***	***Instruments/Methods (M)***
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	MS2 - ICP-MS PE NexION/SW-846 Method 6020B
X - Analytical spike criteria was not met	M - Instrument	NA - Not Applicable
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI147-P-9
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230424-6
Lab ID: 704614
Result Units: mg/Kg

SDG: 704601
SRR: 69508
Matrix: Aqueous
% Solids: NA

Case: 600825
Project: 27927.03.001
Receipt Date: 04/24/2023
Collection Date: NA

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	3,200	D	P1	88.3	177	10	20230503-P003	05/10/2023 13:42
7440-36-0	Antimony	2.21	U	P1	2.21	4.41	1	20230503-P003	05/10/2023 15:32
7440-38-2	Arsenic	2.21	U	P1	2.21	4.41	1	20230503-P003	05/10/2023 15:32
7440-39-3	Barium	0.441	U	P1	0.441	0.883	1	20230503-P003	05/10/2023 15:32
7440-41-7	Beryllium	0.441	U	P1	0.441	0.883	1	20230503-P003	05/10/2023 15:32
7440-69-9	Bismuth	3.53	U	P1	3.53	7.06	1	20230503-P003	05/10/2023 15:32
7440-42-8	Boron	10.4	J	P1	8.83	17.7	1	20230503-P003	05/10/2023 15:32
7440-43-9	Cadmium	0.441	U	P1	0.441	0.883	1	20230503-P003	05/10/2023 15:32
7440-70-2	Calcium	5.44	J	P1	4.41	8.83	1	20230503-P003	05/10/2023 15:32
7440-46-2	Cesium	0.441	UD	MS2	0.441	0.883	10	20230503-P003	05/11/2023 18:57
7440-47-3	Chromium	101		P1	0.441	0.883	1	20230503-P003	05/10/2023 15:32
7440-48-4	Cobalt	0.441	U	P1	0.441	0.883	1	20230503-P003	05/10/2023 15:32
7440-50-8	Copper	0.441	U	P1	0.441	0.883	1	20230503-P003	05/10/2023 15:32
7439-89-6	Iron	8.83	U	P1	8.83	17.7	1	20230503-P003	05/10/2023 15:32
7439-91-0	Lanthanum	1.32	U	P1	1.32	2.65	1	20230503-P003	05/10/2023 15:32
7439-92-1	Lead	1.02	J	P1	0.662	1.32	1	20230503-P003	05/10/2023 15:32
7439-93-2	Lithium	1.32	U	P3	1.32	2.65	1	20230503-P003	05/10/2023 15:47
7439-95-4	Magnesium	4.41	U	P1	4.41	8.83	1	20230503-P003	05/10/2023 15:32
7439-96-5	Manganese	0.441	U	P1	0.441	0.883	1	20230503-P003	05/10/2023 15:32
7439-98-7	Molybdenum	9.98		P1	0.883	1.77	1	20230503-P003	05/10/2023 15:32
7440-02-0	Nickel	2.37		P1	0.441	0.883	1	20230503-P003	05/10/2023 15:32
7440-05-3	Palladium	2.21	U	P1	2.21	4.41	1	20230503-P003	05/10/2023 15:32
7723-14-0	Phosphorus	2,390	D	P1	110	221	10	20230503-P003	05/10/2023 13:42
7440-09-7	Potassium	338		P3	13.2	26.5	1	20230503-P003	05/10/2023 15:47
7782-49-2	Selenium	2.21	U	P1	2.21	4.41	1	20230503-P003	05/10/2023 15:32
7440-21-3	Silicon	36.9		P1	11.0	22.1	1	20230503-P003	05/10/2023 15:32
7440-22-4	Silver	0.883	U	P1	0.883	1.77	1	20230503-P003	05/10/2023 15:32
7440-23-5	Sodium	58,800	D	P3	132	265	10	20230503-P003	05/10/2023 15:12
7440-24-6	Strontium	0.441	U	P1	0.441	0.883	1	20230503-P003	05/10/2023 15:32
7704-34-9	Sulfur	698	D	P1	66.2	132	10	20230503-P003	05/10/2023 13:42
7440-28-0	Thallium	6.62	U	P1	6.62	13.2	1	20230503-P003	05/10/2023 15:32
7440-29-1	Thorium	2.21	U	P1	2.21	4.41	1	20230503-P003	05/10/2023 15:32
7440-31-5	Tin	2.23	J	P1	1.77	3.53	1	20230503-P003	05/10/2023 15:32
7440-32-6	Titanium	0.441	U	P1	0.441	0.883	1	20230503-P003	05/10/2023 15:32
7440-33-7	Tungsten	16.8		P1	2.21	4.41	1	20230503-P003	05/10/2023 15:32
7440-61-1	Uranium	22.1	U	P1	22.1	44.1	1	20230503-P003	05/10/2023 15:32
7440-62-2	Vanadium	1.63		P1	0.441	0.883	1	20230503-P003	05/10/2023 15:32
7440-65-5	Yttrium	0.441	U	P1	0.441	0.883	1	20230503-P003	05/10/2023 15:32
7440-66-6	Zinc	0.662	U	P1	0.662	1.32	1	20230503-P003	05/10/2023 15:32
7440-67-7	Zirconium	1.32	U	P1	1.32	2.65	1	20230503-P003	05/10/2023 15:32

Data Reporting Qualifiers (Qual)	***Columns***	***Instruments/Methods (M)***
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	MS2 - ICP-MS PE NexION/SW-846 Method 6020B
X - Analytical spike criteria was not met	M - Instrument	NA - Not Applicable
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

SwRI ID
PB23E03KE2
Type: Blank

Client: Battelle Memorial Institute PNNL
Task Order: 230424-6
Lab ID: PB23E03KE2
Result Units: mg/Kg

SDG: 704601
SRR: 69508
Matrix: Solid
% Solids: NA

Case: 600825
Project: 27927.03.001
Receipt Date: NA
Collection Date: NA

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	10.0	U	P1	10.0	20.0	1	20230503-P003	05/10/2023 11:30
7440-36-0	Antimony	2.50	U	P1	2.50	5.00	1	20230503-P003	05/10/2023 11:30
7440-38-2	Arsenic	2.50	U	P1	2.50	5.00	1	20230503-P003	05/10/2023 11:30
7440-39-3	Barium	0.500	U	P1	0.500	1.00	1	20230503-P003	05/10/2023 11:30
7440-41-7	Beryllium	0.500	U	P1	0.500	1.00	1	20230503-P003	05/10/2023 11:30
7440-69-9	Bismuth	4.00	U	P1	4.00	8.00	1	20230503-P003	05/10/2023 11:30
7440-42-8	Boron	10.0	U	P1	10.0	20.0	1	20230503-P003	05/10/2023 11:30
7440-43-9	Cadmium	0.500	U	P1	0.500	1.00	1	20230503-P003	05/10/2023 11:30
7440-70-2	Calcium	5.00	U	P1	5.00	10.0	1	20230503-P003	05/10/2023 11:30
7440-46-2	Cesium	0.500	UD	MS2	0.500	1.00	10	20230503-P003	05/11/2023 18:07
7440-47-3	Chromium	0.500	U	P1	0.500	1.00	1	20230503-P003	05/10/2023 11:30
7440-48-4	Cobalt	0.500	U	P1	0.500	1.00	1	20230503-P003	05/10/2023 11:30
7440-50-8	Copper	0.500	U	P1	0.500	1.00	1	20230503-P003	05/10/2023 11:30
7439-89-6	Iron	10.0	U	P1	10.0	20.0	1	20230503-P003	05/10/2023 11:30
7439-91-0	Lanthanum	1.50	U	P1	1.50	3.00	1	20230503-P003	05/10/2023 11:30
7439-92-1	Lead	0.750	U	P1	0.750	1.50	1	20230503-P003	05/10/2023 11:30
7439-93-2	Lithium	1.50	U	P3	1.50	3.00	1	20230503-P003	05/10/2023 14:34
7439-95-4	Magnesium	5.00	U	P1	5.00	10.0	1	20230503-P003	05/10/2023 11:30
7439-96-5	Manganese	0.500	U	P1	0.500	1.00	1	20230503-P003	05/10/2023 11:30
7439-98-7	Molybdenum	1.00	U	P1	1.00	2.00	1	20230503-P003	05/10/2023 11:30
7440-02-0	Nickel	0.500	U	P1	0.500	1.00	1	20230503-P003	05/10/2023 11:30
7440-05-3	Palladium	2.50	U	P1	2.50	5.00	1	20230503-P003	05/10/2023 11:30
7723-14-0	Phosphorus	12.5	U	P1	12.5	25.0	1	20230503-P003	05/10/2023 11:30
7440-09-7	Potassium	15.0	U	P3	15.0	30.0	1	20230503-P003	05/10/2023 14:34
7782-49-2	Selenium	2.50	U	P1	2.50	5.00	1	20230503-P003	05/10/2023 11:30
7440-21-3	Silicon	12.5	U	P1	12.5	25.0	1	20230503-P003	05/10/2023 11:30
7440-22-4	Silver	1.00	U	P1	1.00	2.00	1	20230503-P003	05/10/2023 11:30
7440-23-5	Sodium	15.0	U	P3	15.0	30.0	1	20230503-P003	05/10/2023 14:34
7440-24-6	Strontium	0.500	U	P1	0.500	1.00	1	20230503-P003	05/10/2023 11:30
7704-34-9	Sulfur	7.50	U	P1	7.50	15.0	1	20230503-P003	05/10/2023 11:30
7440-28-0	Thallium	7.50	U	P1	7.50	15.0	1	20230503-P003	05/10/2023 11:30
7440-29-1	Thorium	2.50	U	P1	2.50	5.00	1	20230503-P003	05/10/2023 11:30
7440-31-5	Tin	2.00	U	P1	2.00	4.00	1	20230503-P003	05/10/2023 11:30
7440-32-6	Titanium	0.500	U	P1	0.500	1.00	1	20230503-P003	05/10/2023 11:30
7440-33-7	Tungsten	2.50	U	P1	2.50	5.00	1	20230503-P003	05/10/2023 11:30
7440-61-1	Uranium	25.0	U	P1	25.0	50.0	1	20230503-P003	05/10/2023 11:30
7440-62-2	Vanadium	0.500	U	P1	0.500	1.00	1	20230503-P003	05/10/2023 11:30
7440-65-5	Yttrium	0.500	U	P1	0.500	1.00	1	20230503-P003	05/10/2023 11:30
7440-66-6	Zinc	0.750	U	P1	0.750	1.50	1	20230503-P003	05/10/2023 11:30
7440-67-7	Zirconium	1.50	U	P1	1.50	3.00	1	20230503-P003	05/10/2023 11:30

Data Reporting Qualifiers (Qual)	***Columns***	***Instruments/Methods (M)***
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	MS2 - ICP-MS PE NexION/SW-846 Method 6020B
X - Analytical spike criteria was not met	M - Instrument	NA - Not Applicable
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

Chain of Custody (COC) Form

1. Chain of Custody #	2. Project No./Title	3. Analyses							4. Project Point of Contact	5. Phone No.
COC-DFTP-013	81126: High Level Waste Test Bed (SY-101)	ICP-AES	Alpha Spec (Am, Cm, Np, & Pu)	ICP-MS (Cs)	ICP-MS (Tc)	TOC	TIC		Amy Westesen Amy.Westesen@pnnl.gov	509-371-7908
6. Scope of Work Document(s) Task Order 682609 SWRI Master Agreement 660825										

7. Date	8. Time	9. Sample Identification	10. # Cont.	ICP-AES	Alpha Spec (Am, Cm, Np, & Pu)	ICP-MS (Cs)	ICP-MS (Tc)	TOC	TIC		11. Matrix	12. Comments
5/11/23	08:30	TI147-L-16-A	1	X	X	X					Aqueous	pH = 14
5/11/23	08:30	TI147-L-18-A	1	X	X	X					Aqueous	pH = 14
5/11/23	08:30	TI147-L-20-A	1	X	X	X					Aqueous	pH = 14
5/11/23	08:30	TI147-L-22-A	1	X	X	X					Aqueous	pH = 14
5/11/23	08:30	TI147-L-24-A	1	X	X	X					Aqueous	pH = 14
5/11/23	08:30	TI147-L-26-A	1	X	X	X					Aqueous	pH = 14
5/11/23	08:30	TI147-P-14-A	1	X	X	X					Aqueous	pH = 14
5/11/23	08:30	TI147-P-16-A	1	X	X	X					Aqueous	pH = 14
5/11/23	08:30	TI147-P-18-A	1	X	X	X					Aqueous	pH = 14
5/11/23	08:30	TI147-P-20-A	1	X	X	X					Aqueous	pH = 14
5/11/23	08:30	TI147-Feed-Comp-A	1	X	X	X	X	X	X		Aqueous	pH = 14
5/11/23	08:30	TI147-EFF-Comp-A	1	X	X	X	X	X	X		Aqueous	pH = 14

13. Final Sample Disposition:	14.	15. Samples Preserved? No[x] If "Yes", then note preservation in Box 14.
Dispose on-site		

16. Sample Custodians

Date	Time	Relinquished by	Date	Time	Received by
5/17/23	10:15	amy westesen	05/18/23	13:30	Daniel Mannes

Client: Battelle Memorial Institute PNNL
SRR # 69648
Project # 27927.04.001
Case: 682609
VTSR: 05/18/23
Sample(s) Received: Intact
Temperature: 20.1°C SN # 029926

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI147-EFF-Comp-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705610
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	3,080	D	P1	88.9	178	10	20230621-P014	06/23/2023 12:45
7440-36-0	Antimony	2.22	U	P1	2.22	4.44	1	20230621-P014	06/23/2023 14:23
7440-38-2	Arsenic	2.22	U	P1	2.22	4.44	1	20230621-P014	06/23/2023 14:23
7440-39-3	Barium	0.444	U	P1	0.444	0.889	1	20230621-P014	06/23/2023 14:23
7440-41-7	Beryllium	0.444	U	P1	0.444	0.889	1	20230621-P014	06/23/2023 14:23
7440-69-9	Bismuth	3.55	U	P1	3.55	7.11	1	20230621-P014	06/23/2023 14:23
7440-42-8	Boron	9.26	J	P1	8.89	17.8	1	20230621-P014	06/23/2023 14:23
7440-43-9	Cadmium	0.444	U	P1	0.444	0.889	1	20230621-P014	06/23/2023 14:23
7440-70-2	Calcium	4.77	J	P1	4.44	8.89	1	20230621-P014	06/23/2023 14:23
7440-47-3	Chromium	97.6		P1	0.444	0.889	1	20230621-P014	06/23/2023 14:23
7440-48-4	Cobalt	0.444	U	P1	0.444	0.889	1	20230621-P014	06/23/2023 14:23
7440-50-8	Copper	0.444	U	P1	0.444	0.889	1	20230621-P014	06/23/2023 14:23
7439-89-6	Iron	8.89	U	P1	8.89	17.8	1	20230621-P014	06/23/2023 14:23
7439-91-0	Lanthanum	1.33	U	P1	1.33	2.67	1	20230621-P014	06/23/2023 14:23
7439-92-1	Lead	0.979	J	P1	0.666	1.33	1	20230621-P014	06/23/2023 14:23
7439-93-2	Lithium	1.33	U	P3	1.33	2.67	1	20230621-P014	06/23/2023 16:32
7439-95-4	Magnesium	4.44	U	P1	4.44	8.89	1	20230621-P014	06/23/2023 14:23
7439-96-5	Manganese	0.444	U	P1	0.444	0.889	1	20230621-P014	06/23/2023 14:23
7439-98-7	Molybdenum	9.38		P1	0.889	1.78	1	20230621-P014	06/23/2023 14:23
7440-02-0	Nickel	1.12		P1	0.444	0.889	1	20230621-P014	06/23/2023 14:23
7440-05-3	Palladium	2.22	U	P1	2.22	4.44	1	20230621-P014	06/23/2023 14:23
7723-14-0	Phosphorus	2,180	D	P1	111	222	10	20230621-P014	06/23/2023 12:45
7440-09-7	Potassium	316		P3	13.3	26.7	1	20230621-P014	06/23/2023 16:32
7782-49-2	Selenium	2.22	U	P1	2.22	4.44	1	20230621-P014	06/23/2023 14:23
7440-21-3	Silicon	20.8	J	P1	11.1	22.2	1	20230621-P014	06/23/2023 14:23
7440-22-4	Silver	0.889	U	P1	0.889	1.78	1	20230621-P014	06/23/2023 14:23
7440-23-5	Sodium	56,700	D	P3	133	267	10	20230621-P014	06/23/2023 16:04
7440-24-6	Strontium	0.444	U	P1	0.444	0.889	1	20230621-P014	06/23/2023 14:23
7704-34-9	Sulfur	681		P1	6.66	13.3	1	20230621-P014	06/23/2023 14:23
7440-28-0	Thallium	6.66	U	P1	6.66	13.3	1	20230621-P014	06/23/2023 14:23
7440-29-1	Thorium	2.22	U	P1	2.22	4.44	1	20230621-P014	06/23/2023 14:23
7440-31-5	Tin	2.68	J	P1	1.78	3.55	1	20230621-P014	06/23/2023 14:23
7440-32-6	Titanium	0.444	U	P1	0.444	0.889	1	20230621-P014	06/23/2023 14:23
7440-33-7	Tungsten	16.7		P1	2.22	4.44	1	20230621-P014	06/23/2023 14:23
7440-61-1	Uranium	22.2	U	P1	22.2	44.4	1	20230621-P014	06/23/2023 14:23
7440-62-2	Vanadium	1.46		P1	0.444	0.889	1	20230621-P014	06/23/2023 14:23
7440-65-5	Yttrium	0.444	U	P1	0.444	0.889	1	20230621-P014	06/23/2023 14:23
7440-66-6	Zinc	0.666	U	P1	0.666	1.33	1	20230621-P014	06/23/2023 14:23
7440-67-7	Zirconium	1.33	U	P1	1.33	2.67	1	20230621-P014	06/23/2023 14:23

Data Reporting Qualifiers (Qual)	***Columns***	***Instruments/Methods (M)***
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	NA - Not Applicable
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI147-Feed-Comp-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705611
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	3,370	D	P1	88.0	176	10	20230621-P014	06/23/2023 12:50
7440-36-0	Antimony	2.20	U	P1	2.20	4.40	1	20230621-P014	06/23/2023 14:29
7440-38-2	Arsenic	2.20	U	P1	2.20	4.40	1	20230621-P014	06/23/2023 14:29
7440-39-3	Barium	0.440	U	P1	0.440	0.880	1	20230621-P014	06/23/2023 14:29
7440-41-7	Beryllium	0.440	U	P1	0.440	0.880	1	20230621-P014	06/23/2023 14:29
7440-69-9	Bismuth	3.52	U	P1	3.52	7.04	1	20230621-P014	06/23/2023 14:29
7440-42-8	Boron	11.2	J	P1	8.80	17.6	1	20230621-P014	06/23/2023 14:29
7440-43-9	Cadmium	0.440	U	P1	0.440	0.880	1	20230621-P014	06/23/2023 14:29
7440-70-2	Calcium	12.1		P1	4.40	8.80	1	20230621-P014	06/23/2023 14:29
7440-47-3	Chromium	105		P1	0.440	0.880	1	20230621-P014	06/23/2023 14:29
7440-48-4	Cobalt	0.440	U	P1	0.440	0.880	1	20230621-P014	06/23/2023 14:29
7440-50-8	Copper	0.440	U	P1	0.440	0.880	1	20230621-P014	06/23/2023 14:29
7439-89-6	Iron	8.80	U	P1	8.80	17.6	1	20230621-P014	06/23/2023 14:29
7439-91-0	Lanthanum	1.32	U	P1	1.32	2.64	1	20230621-P014	06/23/2023 14:29
7439-92-1	Lead	1.67		P1	0.660	1.32	1	20230621-P014	06/23/2023 14:29
7439-93-2	Lithium	1.32	U	P3	1.32	2.64	1	20230621-P014	06/23/2023 16:34
7439-95-4	Magnesium	4.40	U	P1	4.40	8.80	1	20230621-P014	06/23/2023 14:29
7439-96-5	Manganese	0.440	U	P1	0.440	0.880	1	20230621-P014	06/23/2023 14:29
7439-98-7	Molybdenum	10.0		P1	0.880	1.76	1	20230621-P014	06/23/2023 14:29
7440-02-0	Nickel	2.05		P1	0.440	0.880	1	20230621-P014	06/23/2023 14:29
7440-05-3	Palladium	2.20	U	P1	2.20	4.40	1	20230621-P014	06/23/2023 14:29
7723-14-0	Phosphorus	2,360	D	P1	110	220	10	20230621-P014	06/23/2023 12:50
7440-09-7	Potassium	348		P3	13.2	26.4	1	20230621-P014	06/23/2023 16:34
7782-49-2	Selenium	2.20	U	P1	2.20	4.40	1	20230621-P014	06/23/2023 14:29
7440-21-3	Silicon	29.8		P1	11.0	22.0	1	20230621-P014	06/23/2023 14:29
7440-22-4	Silver	0.880	U	P1	0.880	1.76	1	20230621-P014	06/23/2023 14:29
7440-23-5	Sodium	59,600	D	P3	132	264	10	20230621-P014	06/23/2023 16:05
7440-24-6	Strontium	0.440	U	P1	0.440	0.880	1	20230621-P014	06/23/2023 14:29
7704-34-9	Sulfur	724		P1	6.60	13.2	1	20230621-P014	06/23/2023 14:29
7440-28-0	Thallium	6.60	U	P1	6.60	13.2	1	20230621-P014	06/23/2023 14:29
7440-29-1	Thorium	2.20	U	P1	2.20	4.40	1	20230621-P014	06/23/2023 14:29
7440-31-5	Tin	2.94	J	P1	1.76	3.52	1	20230621-P014	06/23/2023 14:29
7440-32-6	Titanium	0.440	U	P1	0.440	0.880	1	20230621-P014	06/23/2023 14:29
7440-33-7	Tungsten	17.1		P1	2.20	4.40	1	20230621-P014	06/23/2023 14:29
7440-61-1	Uranium	22.0	U	P1	22.0	44.0	1	20230621-P014	06/23/2023 14:29
7440-62-2	Vanadium	1.48		P1	0.440	0.880	1	20230621-P014	06/23/2023 14:29
7440-65-5	Yttrium	0.440	U	P1	0.440	0.880	1	20230621-P014	06/23/2023 14:29
7440-66-6	Zinc	0.660	U	P1	0.660	1.32	1	20230621-P014	06/23/2023 14:29
7440-67-7	Zirconium	1.32	U	P1	1.32	2.64	1	20230621-P014	06/23/2023 14:29

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	NA - Not Applicable
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI47-L-16-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705612
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	3,150	D	P1	88.2	176	10	20230621-P014	06/23/2023 12:56
7440-36-0	Antimony	2.20	U	P1	2.20	4.41	1	20230621-P014	06/23/2023 14:34
7440-38-2	Arsenic	2.29	J	P1	2.20	4.41	1	20230621-P014	06/23/2023 14:34
7440-39-3	Barium	0.441	U	P1	0.441	0.882	1	20230621-P014	06/23/2023 14:34
7440-41-7	Beryllium	0.441	U	P1	0.441	0.882	1	20230621-P014	06/23/2023 14:34
7440-69-9	Bismuth	3.53	U	P1	3.53	7.05	1	20230621-P014	06/23/2023 14:34
7440-42-8	Boron	32.3		P1	8.82	17.6	1	20230621-P014	06/23/2023 14:34
7440-43-9	Cadmium	0.441	U	P1	0.441	0.882	1	20230621-P014	06/23/2023 14:34
7440-70-2	Calcium	5.16	J	P1	4.41	8.82	1	20230621-P014	06/23/2023 14:34
7440-47-3	Chromium	101		P1	0.441	0.882	1	20230621-P014	06/23/2023 14:34
7440-48-4	Cobalt	0.441	U	P1	0.441	0.882	1	20230621-P014	06/23/2023 14:34
7440-50-8	Copper	0.441	U	P1	0.441	0.882	1	20230621-P014	06/23/2023 14:34
7439-89-6	Iron	8.82	U	P1	8.82	17.6	1	20230621-P014	06/23/2023 14:34
7439-91-0	Lanthanum	1.32	U	P1	1.32	2.65	1	20230621-P014	06/23/2023 14:34
7439-92-1	Lead	1.11	J	P1	0.661	1.32	1	20230621-P014	06/23/2023 14:34
7439-93-2	Lithium	1.32	U	P3	1.32	2.65	1	20230621-P014	06/23/2023 16:35
7439-95-4	Magnesium	4.41	U	P1	4.41	8.82	1	20230621-P014	06/23/2023 14:34
7439-96-5	Manganese	0.441	U	P1	0.441	0.882	1	20230621-P014	06/23/2023 14:34
7439-98-7	Molybdenum	9.86		P1	0.882	1.76	1	20230621-P014	06/23/2023 14:34
7440-02-0	Nickel	1.23		P1	0.441	0.882	1	20230621-P014	06/23/2023 14:34
7440-05-3	Palladium	2.20	U	P1	2.20	4.41	1	20230621-P014	06/23/2023 14:34
7723-14-0	Phosphorus	2,320	D	P1	110	220	10	20230621-P014	06/23/2023 12:56
7440-09-7	Potassium	342		P3	13.2	26.5	1	20230621-P014	06/23/2023 16:35
7782-49-2	Selenium	2.20	U	P1	2.20	4.41	1	20230621-P014	06/23/2023 14:34
7440-21-3	Silicon	91.3		P1	11.0	22.0	1	20230621-P014	06/23/2023 14:34
7440-22-4	Silver	0.882	U	P1	0.882	1.76	1	20230621-P014	06/23/2023 14:34
7440-23-5	Sodium	57,700	D	P3	132	265	10	20230621-P014	06/23/2023 16:07
7440-24-6	Strontium	0.441	U	P1	0.441	0.882	1	20230621-P014	06/23/2023 14:34
7704-34-9	Sulfur	703		P1	6.61	13.2	1	20230621-P014	06/23/2023 14:34
7440-28-0	Thallium	6.61	U	P1	6.61	13.2	1	20230621-P014	06/23/2023 14:34
7440-29-1	Thorium	2.20	U	P1	2.20	4.41	1	20230621-P014	06/23/2023 14:34
7440-31-5	Tin	2.93	J	P1	1.76	3.53	1	20230621-P014	06/23/2023 14:34
7440-32-6	Titanium	0.441	U	P1	0.441	0.882	1	20230621-P014	06/23/2023 14:34
7440-33-7	Tungsten	17.0		P1	2.20	4.41	1	20230621-P014	06/23/2023 14:34
7440-61-1	Uranium	22.0	U	P1	22.0	44.1	1	20230621-P014	06/23/2023 14:34
7440-62-2	Vanadium	1.57		P1	0.441	0.882	1	20230621-P014	06/23/2023 14:34
7440-65-5	Yttrium	0.441	U	P1	0.441	0.882	1	20230621-P014	06/23/2023 14:34
7440-66-6	Zinc	0.661	U	P1	0.661	1.32	1	20230621-P014	06/23/2023 14:34
7440-67-7	Zirconium	1.32	U	P1	1.32	2.65	1	20230621-P014	06/23/2023 14:34

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	NA - Not Applicable
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI147-L-18-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705613
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	3,030	D	P1	90.2	180	10	20230621-P014	06/23/2023 13:23
7440-36-0	Antimony	2.25	U	P1	2.25	4.51	1	20230621-P014	06/23/2023 14:51
7440-38-2	Arsenic	2.25	U	P1	2.25	4.51	1	20230621-P014	06/23/2023 14:51
7440-39-3	Barium	0.451	U	P1	0.451	0.902	1	20230621-P014	06/23/2023 14:51
7440-41-7	Beryllium	0.451	U	P1	0.451	0.902	1	20230621-P014	06/23/2023 14:51
7440-69-9	Bismuth	3.61	U	P1	3.61	7.21	1	20230621-P014	06/23/2023 14:51
7440-42-8	Boron	36.5		P1	9.02	18.0	1	20230621-P014	06/23/2023 14:51
7440-43-9	Cadmium	0.451	U	P1	0.451	0.902	1	20230621-P014	06/23/2023 14:51
7440-70-2	Calcium	4.97	J	P1	4.51	9.02	1	20230621-P014	06/23/2023 14:51
7440-47-3	Chromium	98.0		P1	0.451	0.902	1	20230621-P014	06/23/2023 14:51
7440-48-4	Cobalt	0.451	U	P1	0.451	0.902	1	20230621-P014	06/23/2023 14:51
7440-50-8	Copper	0.451	U	P1	0.451	0.902	1	20230621-P014	06/23/2023 14:51
7439-89-6	Iron	9.02	U	P1	9.02	18.0	1	20230621-P014	06/23/2023 14:51
7439-91-0	Lanthanum	1.35	U	P1	1.35	2.71	1	20230621-P014	06/23/2023 14:51
7439-92-1	Lead	1.14	J	P1	0.676	1.35	1	20230621-P014	06/23/2023 14:51
7439-93-2	Lithium	1.35	U	P3	1.35	2.71	1	20230621-P014	06/23/2023 16:41
7439-95-4	Magnesium	4.51	U	P1	4.51	9.02	1	20230621-P014	06/23/2023 14:51
7439-96-5	Manganese	0.451	U	P1	0.451	0.902	1	20230621-P014	06/23/2023 14:51
7439-98-7	Molybdenum	9.68		P1	0.902	1.80	1	20230621-P014	06/23/2023 14:51
7440-02-0	Nickel	1.17		P1	0.451	0.902	1	20230621-P014	06/23/2023 14:51
7440-05-3	Palladium	2.25	U	P1	2.25	4.51	1	20230621-P014	06/23/2023 14:51
7723-14-0	Phosphorus	2,270	D	P1	113	225	10	20230621-P014	06/23/2023 13:23
7440-09-7	Potassium	340		P3	13.5	27.1	1	20230621-P014	06/23/2023 16:41
7782-49-2	Selenium	2.25	U	P1	2.25	4.51	1	20230621-P014	06/23/2023 14:51
7440-21-3	Silicon	89.3		P1	11.3	22.5	1	20230621-P014	06/23/2023 14:51
7440-22-4	Silver	0.902	U	P1	0.902	1.80	1	20230621-P014	06/23/2023 14:51
7440-23-5	Sodium	57,800	D	P3	135	271	10	20230621-P014	06/23/2023 16:15
7440-24-6	Strontium	0.451	U	P1	0.451	0.902	1	20230621-P014	06/23/2023 14:51
7704-34-9	Sulfur	687		P1	6.76	13.5	1	20230621-P014	06/23/2023 14:51
7440-28-0	Thallium	6.76	U	P1	6.76	13.5	1	20230621-P014	06/23/2023 14:51
7440-29-1	Thorium	2.25	U	P1	2.25	4.51	1	20230621-P014	06/23/2023 14:51
7440-31-5	Tin	2.00	J	P1	1.80	3.61	1	20230621-P014	06/23/2023 14:51
7440-32-6	Titanium	0.451	U	P1	0.451	0.902	1	20230621-P014	06/23/2023 14:51
7440-33-7	Tungsten	16.3		P1	2.25	4.51	1	20230621-P014	06/23/2023 14:51
7440-61-1	Uranium	22.5	U	P1	22.5	45.1	1	20230621-P014	06/23/2023 14:51
7440-62-2	Vanadium	1.54		P1	0.451	0.902	1	20230621-P014	06/23/2023 14:51
7440-65-5	Yttrium	0.451	U	P1	0.451	0.902	1	20230621-P014	06/23/2023 14:51
7440-66-6	Zinc	0.676	U	P1	0.676	1.35	1	20230621-P014	06/23/2023 14:51
7440-67-7	Zirconium	1.35	U	P1	1.35	2.71	1	20230621-P014	06/23/2023 14:51

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	NA - Not Applicable
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI47-L-20-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705614
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	3,440	D	P1	89.1	178	10	20230621-P014	06/23/2023 13:29
7440-36-0	Antimony	2.23	U	P1	2.23	4.46	1	20230621-P014	06/23/2023 14:56
7440-38-2	Arsenic	2.23	U	P1	2.23	4.46	1	20230621-P014	06/23/2023 14:56
7440-39-3	Barium	0.446	U	P1	0.446	0.891	1	20230621-P014	06/23/2023 14:56
7440-41-7	Beryllium	0.446	U	P1	0.446	0.891	1	20230621-P014	06/23/2023 14:56
7440-69-9	Bismuth	3.57	U	P1	3.57	7.13	1	20230621-P014	06/23/2023 14:56
7440-42-8	Boron	30.8		P1	8.91	17.8	1	20230621-P014	06/23/2023 14:56
7440-43-9	Cadmium	0.446	U	P1	0.446	0.891	1	20230621-P014	06/23/2023 14:56
7440-70-2	Calcium	5.15	J	P1	4.46	8.91	1	20230621-P014	06/23/2023 14:56
7440-47-3	Chromium	98.4		P1	0.446	0.891	1	20230621-P014	06/23/2023 14:56
7440-48-4	Cobalt	0.446	U	P1	0.446	0.891	1	20230621-P014	06/23/2023 14:56
7440-50-8	Copper	0.446	U	P1	0.446	0.891	1	20230621-P014	06/23/2023 14:56
7439-89-6	Iron	8.91	U	P1	8.91	17.8	1	20230621-P014	06/23/2023 14:56
7439-91-0	Lanthanum	1.34	U	P1	1.34	2.67	1	20230621-P014	06/23/2023 14:56
7439-92-1	Lead	1.02	J	P1	0.669	1.34	1	20230621-P014	06/23/2023 14:56
7439-93-2	Lithium	1.34	U	P3	1.34	2.67	1	20230621-P014	06/23/2023 16:42
7439-95-4	Magnesium	4.46	U	P1	4.46	8.91	1	20230621-P014	06/23/2023 14:56
7439-96-5	Manganese	0.446	U	P1	0.446	0.891	1	20230621-P014	06/23/2023 14:56
7439-98-7	Molybdenum	9.79		P1	0.891	1.78	1	20230621-P014	06/23/2023 14:56
7440-02-0	Nickel	1.11		P1	0.446	0.891	1	20230621-P014	06/23/2023 14:56
7440-05-3	Palladium	2.23	U	P1	2.23	4.46	1	20230621-P014	06/23/2023 14:56
7723-14-0	Phosphorus	2,620	D	P1	111	223	10	20230621-P014	06/23/2023 13:29
7440-09-7	Potassium	339		P3	13.4	26.7	1	20230621-P014	06/23/2023 16:42
7782-49-2	Selenium	2.23	U	P1	2.23	4.46	1	20230621-P014	06/23/2023 14:56
7440-21-3	Silicon	85.1		P1	11.1	22.3	1	20230621-P014	06/23/2023 14:56
7440-22-4	Silver	0.891	U	P1	0.891	1.78	1	20230621-P014	06/23/2023 14:56
7440-23-5	Sodium	56,900	D	P3	134	267	10	20230621-P014	06/23/2023 16:16
7440-24-6	Strontium	0.446	U	P1	0.446	0.891	1	20230621-P014	06/23/2023 14:56
7704-34-9	Sulfur	699		P1	6.69	13.4	1	20230621-P014	06/23/2023 14:56
7440-28-0	Thallium	6.69	U	P1	6.69	13.4	1	20230621-P014	06/23/2023 14:56
7440-29-1	Thorium	2.23	U	P1	2.23	4.46	1	20230621-P014	06/23/2023 14:56
7440-31-5	Tin	1.96	J	P1	1.78	3.57	1	20230621-P014	06/23/2023 14:56
7440-32-6	Titanium	0.446	U	P1	0.446	0.891	1	20230621-P014	06/23/2023 14:56
7440-33-7	Tungsten	16.8		P1	2.23	4.46	1	20230621-P014	06/23/2023 14:56
7440-61-1	Uranium	22.3	U	P1	22.3	44.6	1	20230621-P014	06/23/2023 14:56
7440-62-2	Vanadium	1.53		P1	0.446	0.891	1	20230621-P014	06/23/2023 14:56
7440-65-5	Yttrium	0.446	U	P1	0.446	0.891	1	20230621-P014	06/23/2023 14:56
7440-66-6	Zinc	0.669	U	P1	0.669	1.34	1	20230621-P014	06/23/2023 14:56
7440-67-7	Zirconium	1.34	U	P1	1.34	2.67	1	20230621-P014	06/23/2023 14:56

Data Reporting Qualifiers (Qual)	***Columns***	***Instruments/Methods (M)***
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	NA - Not Applicable
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI147-L-22-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705615
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	3,270	D	P1	88.3	177	10	20230621-P014	06/23/2023 13:34
7440-36-0	Antimony	2.21	U	P1	2.21	4.42	1	20230621-P014	06/23/2023 15:02
7440-38-2	Arsenic	2.21	U	P1	2.21	4.42	1	20230621-P014	06/23/2023 15:02
7440-39-3	Barium	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:02
7440-41-7	Beryllium	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:02
7440-69-9	Bismuth	3.53	U	P1	3.53	7.07	1	20230621-P014	06/23/2023 15:02
7440-42-8	Boron	21.6		P1	8.83	17.7	1	20230621-P014	06/23/2023 15:02
7440-43-9	Cadmium	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:02
7440-70-2	Calcium	5.51	J	P1	4.42	8.83	1	20230621-P014	06/23/2023 15:02
7440-47-3	Chromium	99.6		P1	0.442	0.883	1	20230621-P014	06/23/2023 15:02
7440-48-4	Cobalt	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:02
7440-50-8	Copper	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:02
7439-89-6	Iron	8.83	U	P1	8.83	17.7	1	20230621-P014	06/23/2023 15:02
7439-91-0	Lanthanum	1.32	U	P1	1.32	2.65	1	20230621-P014	06/23/2023 15:02
7439-92-1	Lead	0.944	J	P1	0.662	1.32	1	20230621-P014	06/23/2023 15:02
7439-93-2	Lithium	1.32	U	P3	1.32	2.65	1	20230621-P014	06/23/2023 16:44
7439-95-4	Magnesium	4.42	U	P1	4.42	8.83	1	20230621-P014	06/23/2023 15:02
7439-96-5	Manganese	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:02
7439-98-7	Molybdenum	10.1		P1	0.883	1.77	1	20230621-P014	06/23/2023 15:02
7440-02-0	Nickel	1.21		P1	0.442	0.883	1	20230621-P014	06/23/2023 15:02
7440-05-3	Palladium	2.21	U	P1	2.21	4.42	1	20230621-P014	06/23/2023 15:02
7723-14-0	Phosphorus	2,500	D	P1	110	221	10	20230621-P014	06/23/2023 13:34
7440-09-7	Potassium	345		P3	13.2	26.5	1	20230621-P014	06/23/2023 16:44
7782-49-2	Selenium	2.21	U	P1	2.21	4.42	1	20230621-P014	06/23/2023 15:02
7440-21-3	Silicon	60.0		P1	11.0	22.1	1	20230621-P014	06/23/2023 15:02
7440-22-4	Silver	0.883	U	P1	0.883	1.77	1	20230621-P014	06/23/2023 15:02
7440-23-5	Sodium	56,600	D	P3	132	265	10	20230621-P014	06/23/2023 16:18
7440-24-6	Strontium	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:02
7704-34-9	Sulfur	699		P1	6.62	13.2	1	20230621-P014	06/23/2023 15:02
7440-28-0	Thallium	6.62	U	P1	6.62	13.2	1	20230621-P014	06/23/2023 15:02
7440-29-1	Thorium	2.21	U	P1	2.21	4.42	1	20230621-P014	06/23/2023 15:02
7440-31-5	Tin	1.93	J	P1	1.77	3.53	1	20230621-P014	06/23/2023 15:02
7440-32-6	Titanium	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:02
7440-33-7	Tungsten	16.1		P1	2.21	4.42	1	20230621-P014	06/23/2023 15:02
7440-61-1	Uranium	22.1	U	P1	22.1	44.2	1	20230621-P014	06/23/2023 15:02
7440-62-2	Vanadium	1.41		P1	0.442	0.883	1	20230621-P014	06/23/2023 15:02
7440-65-5	Yttrium	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:02
7440-66-6	Zinc	0.662	U	P1	0.662	1.32	1	20230621-P014	06/23/2023 15:02
7440-67-7	Zirconium	1.32	U	P1	1.32	2.65	1	20230621-P014	06/23/2023 15:02

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	NA - Not Applicable
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI147-L-24-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705616
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	3,080	D	P1	89.1	178	10	20230621-P014	06/23/2023 13:39
7440-36-0	Antimony	2.23	U	P1	2.23	4.46	1	20230621-P014	06/23/2023 15:07
7440-38-2	Arsenic	2.31	J	P1	2.23	4.46	1	20230621-P014	06/23/2023 15:07
7440-39-3	Barium	0.446	U	P1	0.446	0.891	1	20230621-P014	06/23/2023 15:07
7440-41-7	Beryllium	0.446	U	P1	0.446	0.891	1	20230621-P014	06/23/2023 15:07
7440-69-9	Bismuth	3.56	U	P1	3.56	7.13	1	20230621-P014	06/23/2023 15:07
7440-42-8	Boron	24.5		P1	8.91	17.8	1	20230621-P014	06/23/2023 15:07
7440-43-9	Cadmium	0.446	U	P1	0.446	0.891	1	20230621-P014	06/23/2023 15:07
7440-70-2	Calcium	5.40	J	P1	4.46	8.91	1	20230621-P014	06/23/2023 15:07
7440-47-3	Chromium	99.6		P1	0.446	0.891	1	20230621-P014	06/23/2023 15:07
7440-48-4	Cobalt	0.446	U	P1	0.446	0.891	1	20230621-P014	06/23/2023 15:07
7440-50-8	Copper	0.446	U	P1	0.446	0.891	1	20230621-P014	06/23/2023 15:07
7439-89-6	Iron	8.91	U	P1	8.91	17.8	1	20230621-P014	06/23/2023 15:07
7439-91-0	Lanthanum	1.34	U	P1	1.34	2.67	1	20230621-P014	06/23/2023 15:07
7439-92-1	Lead	1.07	J	P1	0.668	1.34	1	20230621-P014	06/23/2023 15:07
7439-93-2	Lithium	1.34	U	P3	1.34	2.67	1	20230621-P014	06/23/2023 16:46
7439-95-4	Magnesium	4.46	U	P1	4.46	8.91	1	20230621-P014	06/23/2023 15:07
7439-96-5	Manganese	0.446	U	P1	0.446	0.891	1	20230621-P014	06/23/2023 15:07
7439-98-7	Molybdenum	9.96		P1	0.891	1.78	1	20230621-P014	06/23/2023 15:07
7440-02-0	Nickel	1.22		P1	0.446	0.891	1	20230621-P014	06/23/2023 15:07
7440-05-3	Palladium	2.23	U	P1	2.23	4.46	1	20230621-P014	06/23/2023 15:07
7723-14-0	Phosphorus	2,290	D	P1	111	223	10	20230621-P014	06/23/2023 13:39
7440-09-7	Potassium	333		P3	13.4	26.7	1	20230621-P014	06/23/2023 16:46
7782-49-2	Selenium	2.23	U	P1	2.23	4.46	1	20230621-P014	06/23/2023 15:07
7440-21-3	Silicon	68.7		P1	11.1	22.3	1	20230621-P014	06/23/2023 15:07
7440-22-4	Silver	0.891	U	P1	0.891	1.78	1	20230621-P014	06/23/2023 15:07
7440-23-5	Sodium	57,600	D	P3	134	267	10	20230621-P014	06/23/2023 16:19
7440-24-6	Strontium	0.446	U	P1	0.446	0.891	1	20230621-P014	06/23/2023 15:07
7704-34-9	Sulfur	693		P1	6.68	13.4	1	20230621-P014	06/23/2023 15:07
7440-28-0	Thallium	6.68	U	P1	6.68	13.4	1	20230621-P014	06/23/2023 15:07
7440-29-1	Thorium	2.23	U	P1	2.23	4.46	1	20230621-P014	06/23/2023 15:07
7440-31-5	Tin	2.38	J	P1	1.78	3.56	1	20230621-P014	06/23/2023 15:07
7440-32-6	Titanium	0.446	U	P1	0.446	0.891	1	20230621-P014	06/23/2023 15:07
7440-33-7	Tungsten	16.8		P1	2.23	4.46	1	20230621-P014	06/23/2023 15:07
7440-61-1	Uranium	22.3	U	P1	22.3	44.6	1	20230621-P014	06/23/2023 15:07
7440-62-2	Vanadium	1.55		P1	0.446	0.891	1	20230621-P014	06/23/2023 15:07
7440-65-5	Yttrium	0.446	U	P1	0.446	0.891	1	20230621-P014	06/23/2023 15:07
7440-66-6	Zinc	0.668	U	P1	0.668	1.34	1	20230621-P014	06/23/2023 15:07
7440-67-7	Zirconium	1.34	U	P1	1.34	2.67	1	20230621-P014	06/23/2023 15:07

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	NA - Not Applicable
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI147-L-26-A

Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705617
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	3,110	D	P1	88.6	177	10	20230621-P014	06/23/2023 13:45
7440-36-0	Antimony	2.22	U	P1	2.22	4.43	1	20230621-P014	06/23/2023 15:13
7440-38-2	Arsenic	2.22	U	P1	2.22	4.43	1	20230621-P014	06/23/2023 15:13
7440-39-3	Barium	0.443	U	P1	0.443	0.886	1	20230621-P014	06/23/2023 15:13
7440-41-7	Beryllium	0.443	U	P1	0.443	0.886	1	20230621-P014	06/23/2023 15:13
7440-69-9	Bismuth	3.54	U	P1	3.54	7.09	1	20230621-P014	06/23/2023 15:13
7440-42-8	Boron	21.5		P1	8.86	17.7	1	20230621-P014	06/23/2023 15:13
7440-43-9	Cadmium	0.443	U	P1	0.443	0.886	1	20230621-P014	06/23/2023 15:13
7440-70-2	Calcium	5.45	J	P1	4.43	8.86	1	20230621-P014	06/23/2023 15:13
7440-47-3	Chromium	100		P1	0.443	0.886	1	20230621-P014	06/23/2023 15:13
7440-48-4	Cobalt	0.443	U	P1	0.443	0.886	1	20230621-P014	06/23/2023 15:13
7440-50-8	Copper	0.443	U	P1	0.443	0.886	1	20230621-P014	06/23/2023 15:13
7439-89-6	Iron	8.86	U	P1	8.86	17.7	1	20230621-P014	06/23/2023 15:13
7439-91-0	Lanthanum	1.33	U	P1	1.33	2.66	1	20230621-P014	06/23/2023 15:13
7439-92-1	Lead	1.16	J	P1	0.665	1.33	1	20230621-P014	06/23/2023 15:13
7439-93-2	Lithium	1.33	U	P3	1.33	2.66	1	20230621-P014	06/23/2023 16:48
7439-95-4	Magnesium	4.43	U	P1	4.43	8.86	1	20230621-P014	06/23/2023 15:13
7439-96-5	Manganese	0.443	U	P1	0.443	0.886	1	20230621-P014	06/23/2023 15:13
7439-98-7	Molybdenum	9.96		P1	0.886	1.77	1	20230621-P014	06/23/2023 15:13
7440-02-0	Nickel	1.16		P1	0.443	0.886	1	20230621-P014	06/23/2023 15:13
7440-05-3	Palladium	2.22	U	P1	2.22	4.43	1	20230621-P014	06/23/2023 15:13
7723-14-0	Phosphorus	2,310	D	P1	111	222	10	20230621-P014	06/23/2023 13:45
7440-09-7	Potassium	329		P3	13.3	26.6	1	20230621-P014	06/23/2023 16:48
7782-49-2	Selenium	2.22	U	P1	2.22	4.43	1	20230621-P014	06/23/2023 15:13
7440-21-3	Silicon	54.7		P1	11.1	22.2	1	20230621-P014	06/23/2023 15:13
7440-22-4	Silver	0.886	U	P1	0.886	1.77	1	20230621-P014	06/23/2023 15:13
7440-23-5	Sodium	63,700	D	P3	133	266	10	20230621-P014	06/23/2023 16:21
7440-24-6	Strontium	0.443	U	P1	0.443	0.886	1	20230621-P014	06/23/2023 15:13
7704-34-9	Sulfur	704		P1	6.65	13.3	1	20230621-P014	06/23/2023 15:13
7440-28-0	Thallium	6.65	U	P1	6.65	13.3	1	20230621-P014	06/23/2023 15:13
7440-29-1	Thorium	2.22	U	P1	2.22	4.43	1	20230621-P014	06/23/2023 15:13
7440-31-5	Tin	1.80	J	P1	1.77	3.54	1	20230621-P014	06/23/2023 15:13
7440-32-6	Titanium	0.443	U	P1	0.443	0.886	1	20230621-P014	06/23/2023 15:13
7440-33-7	Tungsten	16.9		P1	2.22	4.43	1	20230621-P014	06/23/2023 15:13
7440-61-1	Uranium	22.2	U	P1	22.2	44.3	1	20230621-P014	06/23/2023 15:13
7440-62-2	Vanadium	1.54		P1	0.443	0.886	1	20230621-P014	06/23/2023 15:13
7440-65-5	Yttrium	0.443	U	P1	0.443	0.886	1	20230621-P014	06/23/2023 15:13
7440-66-6	Zinc	0.665	U	P1	0.665	1.33	1	20230621-P014	06/23/2023 15:13
7440-67-7	Zirconium	1.33	U	P1	1.33	2.66	1	20230621-P014	06/23/2023 15:13

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	NA - Not Applicable
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
T147-P-14-A

Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705618
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	3,020	D	P1	88.3	177	10	20230621-P014	06/23/2023 13:50
7440-36-0	Antimony	2.21	U	P1	2.21	4.42	1	20230621-P014	06/23/2023 15:29
7440-38-2	Arsenic	2.21	U	P1	2.21	4.42	1	20230621-P014	06/23/2023 15:29
7440-39-3	Barium	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:29
7440-41-7	Beryllium	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:29
7440-69-9	Bismuth	3.53	U	P1	3.53	7.06	1	20230621-P014	06/23/2023 15:29
7440-42-8	Boron	40.6		P1	8.83	17.7	1	20230621-P014	06/23/2023 15:29
7440-43-9	Cadmium	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:29
7440-70-2	Calcium	4.94	J	P1	4.42	8.83	1	20230621-P014	06/23/2023 15:29
7440-47-3	Chromium	99.3		P1	0.442	0.883	1	20230621-P014	06/23/2023 15:29
7440-48-4	Cobalt	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:29
7440-50-8	Copper	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:29
7439-89-6	Iron	8.83	U	P1	8.83	17.7	1	20230621-P014	06/23/2023 15:29
7439-91-0	Lanthanum	1.32	U	P1	1.32	2.65	1	20230621-P014	06/23/2023 15:29
7439-92-1	Lead	1.15	J	P1	0.662	1.32	1	20230621-P014	06/23/2023 15:29
7439-93-2	Lithium	1.32	U	P3	1.32	2.65	1	20230621-P014	06/23/2023 16:53
7439-95-4	Magnesium	4.42	U	P1	4.42	8.83	1	20230621-P014	06/23/2023 15:29
7439-96-5	Manganese	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:29
7439-98-7	Molybdenum	9.67		P1	0.883	1.77	1	20230621-P014	06/23/2023 15:29
7440-02-0	Nickel	1.17		P1	0.442	0.883	1	20230621-P014	06/23/2023 15:29
7440-05-3	Palladium	2.21	U	P1	2.21	4.42	1	20230621-P014	06/23/2023 15:29
7723-14-0	Phosphorus	2,350	D	P1	110	221	10	20230621-P014	06/23/2023 13:50
7440-09-7	Potassium	321		P3	13.2	26.5	1	20230621-P014	06/23/2023 16:53
7782-49-2	Selenium	2.21	U	P1	2.21	4.42	1	20230621-P014	06/23/2023 15:29
7440-21-3	Silicon	97.5		P1	11.0	22.1	1	20230621-P014	06/23/2023 15:29
7440-22-4	Silver	0.883	U	P1	0.883	1.77	1	20230621-P014	06/23/2023 15:29
7440-23-5	Sodium	56,600	D	P3	132	265	10	20230621-P014	06/23/2023 16:22
7440-24-6	Strontium	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:29
7704-34-9	Sulfur	697		P1	6.62	13.2	1	20230621-P014	06/23/2023 15:29
7440-28-0	Thallium	6.62	U	P1	6.62	13.2	1	20230621-P014	06/23/2023 15:29
7440-29-1	Thorium	2.21	U	P1	2.21	4.42	1	20230621-P014	06/23/2023 15:29
7440-31-5	Tin	2.21	J	P1	1.77	3.53	1	20230621-P014	06/23/2023 15:29
7440-32-6	Titanium	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:29
7440-33-7	Tungsten	16.6		P1	2.21	4.42	1	20230621-P014	06/23/2023 15:29
7440-61-1	Uranium	22.1	U	P1	22.1	44.2	1	20230621-P014	06/23/2023 15:29
7440-62-2	Vanadium	1.40		P1	0.442	0.883	1	20230621-P014	06/23/2023 15:29
7440-65-5	Yttrium	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:29
7440-66-6	Zinc	0.662	U	P1	0.662	1.32	1	20230621-P014	06/23/2023 15:29
7440-67-7	Zirconium	1.32	U	P1	1.32	2.65	1	20230621-P014	06/23/2023 15:29

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	NA - Not Applicable
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
T147-P-16-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705619
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	3,090	D	P1	89.4	179	10	20230621-P014	06/23/2023 13:56
7440-36-0	Antimony	2.24	U	P1	2.24	4.47	1	20230621-P014	06/23/2023 15:35
7440-38-2	Arsenic	2.24	U	P1	2.24	4.47	1	20230621-P014	06/23/2023 15:35
7440-39-3	Barium	0.447	U	P1	0.447	0.894	1	20230621-P014	06/23/2023 15:35
7440-41-7	Beryllium	0.447	U	P1	0.447	0.894	1	20230621-P014	06/23/2023 15:35
7440-69-9	Bismuth	3.58	U	P1	3.58	7.16	1	20230621-P014	06/23/2023 15:35
7440-42-8	Boron	24.0		P1	8.94	17.9	1	20230621-P014	06/23/2023 15:35
7440-43-9	Cadmium	0.447	U	P1	0.447	0.894	1	20230621-P014	06/23/2023 15:35
7440-70-2	Calcium	4.78	J	P1	4.47	8.94	1	20230621-P014	06/23/2023 15:35
7440-47-3	Chromium	98.1		P1	0.447	0.894	1	20230621-P014	06/23/2023 15:35
7440-48-4	Cobalt	0.447	U	P1	0.447	0.894	1	20230621-P014	06/23/2023 15:35
7440-50-8	Copper	0.447	U	P1	0.447	0.894	1	20230621-P014	06/23/2023 15:35
7439-89-6	Iron	8.94	U	P1	8.94	17.9	1	20230621-P014	06/23/2023 15:35
7439-91-0	Lanthanum	1.34	U	P1	1.34	2.68	1	20230621-P014	06/23/2023 15:35
7439-92-1	Lead	0.902	J	P1	0.671	1.34	1	20230621-P014	06/23/2023 15:35
7439-93-2	Lithium	1.34	U	P3	1.34	2.68	1	20230621-P014	06/23/2023 16:55
7439-95-4	Magnesium	4.47	U	P1	4.47	8.94	1	20230621-P014	06/23/2023 15:35
7439-96-5	Manganese	0.447	U	P1	0.447	0.894	1	20230621-P014	06/23/2023 15:35
7439-98-7	Molybdenum	9.85		P1	0.894	1.79	1	20230621-P014	06/23/2023 15:35
7440-02-0	Nickel	1.19		P1	0.447	0.894	1	20230621-P014	06/23/2023 15:35
7440-05-3	Palladium	2.24	U	P1	2.24	4.47	1	20230621-P014	06/23/2023 15:35
7723-14-0	Phosphorus	2,250	D	P1	112	224	10	20230621-P014	06/23/2023 13:56
7440-09-7	Potassium	322		P3	13.4	26.8	1	20230621-P014	06/23/2023 16:55
7782-49-2	Selenium	2.24	U	P1	2.24	4.47	1	20230621-P014	06/23/2023 15:35
7440-21-3	Silicon	68.9		P1	11.2	22.4	1	20230621-P014	06/23/2023 15:35
7440-22-4	Silver	0.894	U	P1	0.894	1.79	1	20230621-P014	06/23/2023 15:35
7440-23-5	Sodium	56,500	D	P3	134	268	10	20230621-P014	06/23/2023 16:24
7440-24-6	Strontium	0.447	U	P1	0.447	0.894	1	20230621-P014	06/23/2023 15:35
7704-34-9	Sulfur	690		P1	6.71	13.4	1	20230621-P014	06/23/2023 15:35
7440-28-0	Thallium	6.71	U	P1	6.71	13.4	1	20230621-P014	06/23/2023 15:35
7440-29-1	Thorium	2.24	U	P1	2.24	4.47	1	20230621-P014	06/23/2023 15:35
7440-31-5	Tin	3.00	J	P1	1.79	3.58	1	20230621-P014	06/23/2023 15:35
7440-32-6	Titanium	0.447	U	P1	0.447	0.894	1	20230621-P014	06/23/2023 15:35
7440-33-7	Tungsten	16.5		P1	2.24	4.47	1	20230621-P014	06/23/2023 15:35
7440-61-1	Uranium	22.4	U	P1	22.4	44.7	1	20230621-P014	06/23/2023 15:35
7440-62-2	Vanadium	1.53		P1	0.447	0.894	1	20230621-P014	06/23/2023 15:35
7440-65-5	Yttrium	0.447	U	P1	0.447	0.894	1	20230621-P014	06/23/2023 15:35
7440-66-6	Zinc	0.671	U	P1	0.671	1.34	1	20230621-P014	06/23/2023 15:35
7440-67-7	Zirconium	1.34	U	P1	1.34	2.68	1	20230621-P014	06/23/2023 15:35

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	NA - Not Applicable
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
T147-P-18-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705620
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	3,100	D	P1	88.9	178	10	20230621-P014	06/23/2023 14:01
7440-36-0	Antimony	2.22	U	P1	2.22	4.45	1	20230621-P014	06/23/2023 15:40
7440-38-2	Arsenic	2.22	U	P1	2.22	4.45	1	20230621-P014	06/23/2023 15:40
7440-39-3	Barium	0.445	U	P1	0.445	0.889	1	20230621-P014	06/23/2023 15:40
7440-41-7	Beryllium	0.445	U	P1	0.445	0.889	1	20230621-P014	06/23/2023 15:40
7440-69-9	Bismuth	3.56	U	P1	3.56	7.11	1	20230621-P014	06/23/2023 15:40
7440-42-8	Boron	28.9		P1	8.89	17.8	1	20230621-P014	06/23/2023 15:40
7440-43-9	Cadmium	0.445	U	P1	0.445	0.889	1	20230621-P014	06/23/2023 15:40
7440-70-2	Calcium	4.94	J	P1	4.45	8.89	1	20230621-P014	06/23/2023 15:40
7440-47-3	Chromium	99.1		P1	0.445	0.889	1	20230621-P014	06/23/2023 15:40
7440-48-4	Cobalt	0.445	U	P1	0.445	0.889	1	20230621-P014	06/23/2023 15:40
7440-50-8	Copper	0.445	U	P1	0.445	0.889	1	20230621-P014	06/23/2023 15:40
7439-89-6	Iron	8.89	U	P1	8.89	17.8	1	20230621-P014	06/23/2023 15:40
7439-91-0	Lanthanum	1.33	U	P1	1.33	2.67	1	20230621-P014	06/23/2023 15:40
7439-92-1	Lead	1.02	J	P1	0.667	1.33	1	20230621-P014	06/23/2023 15:40
7439-93-2	Lithium	1.33	U	P3	1.33	2.67	1	20230621-P014	06/23/2023 16:57
7439-95-4	Magnesium	4.45	U	P1	4.45	8.89	1	20230621-P014	06/23/2023 15:40
7439-96-5	Manganese	0.445	U	P1	0.445	0.889	1	20230621-P014	06/23/2023 15:40
7439-98-7	Molybdenum	9.59		P1	0.889	1.78	1	20230621-P014	06/23/2023 15:40
7440-02-0	Nickel	1.13		P1	0.445	0.889	1	20230621-P014	06/23/2023 15:40
7440-05-3	Palladium	2.22	U	P1	2.22	4.45	1	20230621-P014	06/23/2023 15:40
7723-14-0	Phosphorus	2,350	D	P1	111	222	10	20230621-P014	06/23/2023 14:01
7440-09-7	Potassium	332		P3	13.3	26.7	1	20230621-P014	06/23/2023 16:57
7782-49-2	Selenium	2.22	U	P1	2.22	4.45	1	20230621-P014	06/23/2023 15:40
7440-21-3	Silicon	73.1		P1	11.1	22.2	1	20230621-P014	06/23/2023 15:40
7440-22-4	Silver	0.889	U	P1	0.889	1.78	1	20230621-P014	06/23/2023 15:40
7440-23-5	Sodium	57,000	D	P3	133	267	10	20230621-P014	06/23/2023 16:25
7440-24-6	Strontium	0.445	U	P1	0.445	0.889	1	20230621-P014	06/23/2023 15:40
7704-34-9	Sulfur	686		P1	6.67	13.3	1	20230621-P014	06/23/2023 15:40
7440-28-0	Thallium	6.67	U	P1	6.67	13.3	1	20230621-P014	06/23/2023 15:40
7440-29-1	Thorium	2.22	U	P1	2.22	4.45	1	20230621-P014	06/23/2023 15:40
7440-31-5	Tin	2.30	J	P1	1.78	3.56	1	20230621-P014	06/23/2023 15:40
7440-32-6	Titanium	0.445	U	P1	0.445	0.889	1	20230621-P014	06/23/2023 15:40
7440-33-7	Tungsten	16.9		P1	2.22	4.45	1	20230621-P014	06/23/2023 15:40
7440-61-1	Uranium	22.2	U	P1	22.2	44.5	1	20230621-P014	06/23/2023 15:40
7440-62-2	Vanadium	1.45		P1	0.445	0.889	1	20230621-P014	06/23/2023 15:40
7440-65-5	Yttrium	0.445	U	P1	0.445	0.889	1	20230621-P014	06/23/2023 15:40
7440-66-6	Zinc	0.667	U	P1	0.667	1.33	1	20230621-P014	06/23/2023 15:40
7440-67-7	Zirconium	1.33	U	P1	1.33	2.67	1	20230621-P014	06/23/2023 15:40

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	NA - Not Applicable
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI47-P-20-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705621
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7429-90-5	Aluminum	3,170	D	P1	88.3	177	10	20230621-P014	06/23/2023 14:07
7440-36-0	Antimony	2.21	U	P1	2.21	4.42	1	20230621-P014	06/23/2023 15:46
7440-38-2	Arsenic	2.21	U	P1	2.21	4.42	1	20230621-P014	06/23/2023 15:46
7440-39-3	Barium	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:46
7440-41-7	Beryllium	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:46
7440-69-9	Bismuth	3.53	U	P1	3.53	7.06	1	20230621-P014	06/23/2023 15:46
7440-42-8	Boron	21.3		P1	8.83	17.7	1	20230621-P014	06/23/2023 15:46
7440-43-9	Cadmium	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:46
7440-70-2	Calcium	4.89	J	P1	4.42	8.83	1	20230621-P014	06/23/2023 15:46
7440-47-3	Chromium	99.8		P1	0.442	0.883	1	20230621-P014	06/23/2023 15:46
7440-48-4	Cobalt	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:46
7440-50-8	Copper	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:46
7439-89-6	Iron	8.83	U	P1	8.83	17.7	1	20230621-P014	06/23/2023 15:46
7439-91-0	Lanthanum	1.32	U	P1	1.32	2.65	1	20230621-P014	06/23/2023 15:46
7439-92-1	Lead	1.06	J	P1	0.662	1.32	1	20230621-P014	06/23/2023 15:46
7439-93-2	Lithium	1.32	U	P3	1.32	2.65	1	20230621-P014	06/23/2023 16:58
7439-95-4	Magnesium	4.42	U	P1	4.42	8.83	1	20230621-P014	06/23/2023 15:46
7439-96-5	Manganese	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:46
7439-98-7	Molybdenum	10.0		P1	0.883	1.77	1	20230621-P014	06/23/2023 15:46
7440-02-0	Nickel	1.18		P1	0.442	0.883	1	20230621-P014	06/23/2023 15:46
7440-05-3	Palladium	2.21	U	P1	2.21	4.42	1	20230621-P014	06/23/2023 15:46
7723-14-0	Phosphorus	2,270	D	P1	110	221	10	20230621-P014	06/23/2023 14:07
7440-09-7	Potassium	331		P3	13.2	26.5	1	20230621-P014	06/23/2023 16:58
7782-49-2	Selenium	2.21	U	P1	2.21	4.42	1	20230621-P014	06/23/2023 15:46
7440-21-3	Silicon	56.8		P1	11.0	22.1	1	20230621-P014	06/23/2023 15:46
7440-22-4	Silver	0.883	U	P1	0.883	1.77	1	20230621-P014	06/23/2023 15:46
7440-23-5	Sodium	57,300	D	P3	132	265	10	20230621-P014	06/23/2023 16:27
7440-24-6	Strontium	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:46
7704-34-9	Sulfur	706		P1	6.62	13.2	1	20230621-P014	06/23/2023 15:46
7440-28-0	Thallium	6.62	U	P1	6.62	13.2	1	20230621-P014	06/23/2023 15:46
7440-29-1	Thorium	2.21	U	P1	2.21	4.42	1	20230621-P014	06/23/2023 15:46
7440-31-5	Tin	2.04	J	P1	1.77	3.53	1	20230621-P014	06/23/2023 15:46
7440-32-6	Titanium	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:46
7440-33-7	Tungsten	16.9		P1	2.21	4.42	1	20230621-P014	06/23/2023 15:46
7440-61-1	Uranium	22.1	U	P1	22.1	44.2	1	20230621-P014	06/23/2023 15:46
7440-62-2	Vanadium	1.52		P1	0.442	0.883	1	20230621-P014	06/23/2023 15:46
7440-65-5	Yttrium	0.442	U	P1	0.442	0.883	1	20230621-P014	06/23/2023 15:46
7440-66-6	Zinc	0.662	U	P1	0.662	1.32	1	20230621-P014	06/23/2023 15:46
7440-67-7	Zirconium	1.32	U	P1	1.32	2.65	1	20230621-P014	06/23/2023 15:46

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	P1 - ICP TJA Trace 1/SW846 Method 6010D
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	P3 - ICP PE Optima 7300DV/SW846 Method 6010D
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	NA - Not Applicable
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

Test Report

SwRI Project #:	27927.04.001
SwRI SDG:	705610
SwRI Task Order:	230526-2
SwRI Sample Receipt:	69648
Date Received:	05/18/2023

Purchase Order #: 682609

Prepared by:

Southwest Research Institute®
Department of Analytical and Environmental Chemistry
6220 Culebra Road
San Antonio, Texas 78238

Prepared for:

Battelle Memorial Institute - PNNL
902 Battelle Boulevard
P.O. Box 999
Richland, WA 99354
Attn: Ms. Amy Westesen

Authorized for Release
08/11/2023 3:00PM
Jackie Ranger, Project Manager
jacqueline.ranger@swri.org
210-522-3320

Mike Dammann
Laboratory Director

SOUTHWEST RESEARCH INSTITUTE
CLIENT: Battelle Memorial Institute PNNL
SwRI Project #: 27927.04.001
SwRI Task Order #: 230526-2
SDG #: 705610
TA #: 682609

CASE NARRATIVE

Client: Battelle Memorial Institute PNNL
SDG: 705610
SwRI Project Number: 27927.04.001
SwRI Task Order Number: 230526-2

TECHNETIUM-99 ANALYSES VIA ICP-MS

The samples were readied for analysis via an open vessel digestion using nitric acid. The resulting digestates were analyzed for Tc-99 by ICP-MS (TAP01-0406-046 Rev25).

All instrument QC criteria were evaluated. The percent recoveries were within 90-110% for the initial and continuing calibration verifications. Tc-99 was not detected above SwRI's limit of detection (LOD) in the initial and continuing calibration blanks. The low level, check standard recoveries were within 80-120%. The percent recoveries for the ICSAB interference check samples were within 80-120%. The limits were met for the ICSA interference check samples. The ICSA limits are the ICSA true value ± 2 times the LOD.

Description of "Qualifier": "U" indicates that an analyte was not detected above SwRI's LOD. "J" indicates that an analyte was detected at the instrument at or above SwRI's LOD, but less than SwRI's LOQ (limit of quantitation). "D" indicates that the reported result was from a dilution of the digestion.

Tc-99 was not detected in the Prep Blank (ID: PB23F21VG3) above SwRI's LOD. Laboratory control samples (IDs: LCS23F21VG9/10) were prepared with the samples. The recoveries were within 80-120%. No duplicates and MS/MSD's were prepared due to limited sample volumes received.

Jacqueline Ranger Digitally signed by Jacqueline Ranger
Date: 2023.08.09 17:06:27 -05'00'

Prepared By

Client: Battelle Memorial Institute PNNL
SDG: 705610
SwRI Project Number: 27927.04.001
SwRI Task Order Number: 230526-2

CESIUM ANALYSIS

Sample aliquots were digested using hydrochloric acid. The resulting digestates were analyzed for cesium by ICP-MS (TAP01-0406-046 Rev25).

All instrument QC criteria were evaluated. The percent recoveries were within 90-110% for the initial and continuing calibration verifications. Cesium was not detected above SwRI's limit of detection (LOD) in the initial and continuing calibration blanks. The low level, check standard recovery was within 80-120%. The percent recovery for the ICSAB interference check sample was within 80-120% for cesium. The limits were met for the ICSA interference check sample. The ICSA limit was the ICSA true value ± 2 times the LOD.

Description of "Qualifier": "U" indicates that an analyte was not detected above SwRI's LOD. "J" indicates that an analyte was detected at the instrument at or above SwRI's LOD, but less than SwRI's limit of quantitation (LOQ). "D" indicates that the reported result was from a dilution of the digestate.

Cesium was not detected in the Prep Blank (ID: PB23F21VG2) above SwRI's LOD. Aqueous lab control samples (IDs: LCS23F21VG7 and LCS23F21VG8) were prepared with the samples. The recoveries for cesium were within 80-120%.

No duplicates and MS/MSD's were prepared due to limited sample volumes received. A post-digestion spike and serial dilution analysis were performed and reported for SwRI system id 705611. The post-digestion spike recovery was within 80-120%. The QC criteria for the serial dilution analyses was met. No limits are applied unless the parent sample concentration is greater than 50 times the LOD. The limit is then 10% difference.

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Date: 2023.08.09 16:08:13 -05'00'

Prepared By

Client: Battelle Memorial Institute PNNL
SDG: 705610
SwRI Project Number: 27927.04.001
SwRI Task Order Number: 230526-2

ICP-AES METALS ANALYSIS

Sample aliquots were digested using hydrochloric acid. The resulting digestates were analyzed via ICP-AES (TAP01-0406-130 Rev18).

All instrument QC criteria were evaluated. Most of the percent recoveries were within 90-110% for the initial and continuing calibration verifications, with one exception for thallium (at 110.8%). No analytes were detected above SwRI's limits of detection (LOD) in the initial and continuing calibration blanks. Most low level, check standard recoveries were within 80-120%; all were within the HASQARD limits of 70-130%. The percent recoveries for the ICSAB interference check samples were within 80-120% for the spiked analytes, except thallium (at 126.6%). The limits were met for the ICSA interference check samples, except thallium. The ICSA limits are the greater of either the ICSA true value ± 2 times the LOD, or 80-120% of the true value. No re-analyses were performed, since thallium was not detected above its LOD in the associated samples. There are no internal standard criteria defined in ICP Method 6010D. However, the ICP internal standard recoveries are reported on Form 14s.

Description of "Qualifier": "U" indicates that an analyte was not detected above SwRI's LOD. "J" indicates that an analyte was detected at the instrument at or above SwRI's LOD, but less than SwRI's limit of quantitation (LOQ). "D" indicates that the reported result was from a dilution of the digestate.

No analytes were detected in the Prep Blank (ID: PB23F21VG2) above SwRI's LODs. Aqueous lab control samples (IDs: LCS23F21VG5/6/7/8) were prepared with the samples. The recoveries for the spiked analytes were within 80-120%, except tin for LCS23F21VG8 at 79.3%. An acceptable tin recovery (at 81.7%) was obtained for LCS23F21VG7. No re-digestion was performed due to the limited sample volumes received and remaining.

No duplicates and MS/MSD's were prepared due to limited sample volumes received. Post-digestion spikes and serial dilution analyses were performed and reported for SwRI system id 705612. The post-digestion spike recoveries were within 80-120% for the spiked analytes. The QC criteria for the serial dilution analyses was met. No limits are applied unless the parent sample concentration is greater than 50 times the LOD. The limit is then 10% difference.

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Date: 2023.08.09 16:50:26 -05'00'

Prepared By

SOUTHWEST RESEARCH INSTITUTE
CLIENT: Battelle Memorial Institute PNNL
SwRI Project #: 27927.04.001
SwRI Task Order #: 230526-2
SDG #: 705610
TA #: 682609

TECHNETIUM-99 RESULTS

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2

SDG: 705610
SRR: 69648

Case: 682609
Project: 27927.04.001

Client Sample ID	Lab Sample ID
TI147-EFF-Comp-A	705610
TI147-Feed-Comp-A	705611

Comments:

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI147-EFF-Comp-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705610
Result Units: mg/Kg

SDG: 705610
SRR:
Matrix: Aqueous
% Solids: NA

Case:
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
14133-76-7	Technetium-99	1.31	D	MS2	0.0584	0.117	100	20230621-P015	08/01/2023 16:40

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	MS2 - ICP-MS PE NexION/SW-846 Method 6020B
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	NA - Not Applicable
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI147-Feed-Comp-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705611
Result Units: mg/Kg

SDG: 705610
SRR:
Matrix: Aqueous
% Solids: NA

Case:
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
14133-76-7	Technetium-99	1.34	D	MS2	0.0549	0.110	100	20230621-P015	08/01/2023 16:43

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	MS2 - ICP-MS PE NexION/SW-846 Method 6020B
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	NA - Not Applicable
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

SwRI ID
PB23F21VG3
Type: Blank

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: PB23F21VG3
Result Units: mg/Kg

SDG: 705610
SRR:
Matrix: Solid
% Solids: NA

Case:
Project: 27927.06.001
Receipt Date: NA
Collection Date: NA

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
14133-76-7	Technetium-99	0.00125	UD	MS2	0.00125	0.00250	2	20230621-P015	08/01/2023 12:11

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	MS2 - ICP-MS PE NexION/SW-846 Method 6020B
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	NA - Not Applicable
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form IIA
Initial and Continuing Calibration Verification

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Result Units: ug/L
Associated Analytical Batches: 20230804-A003

SDG: 705610
SRR: 69648
Initial Calibration Source: See Raw Data
Continuing Calibration Source: See Raw Data

Case: 682609
Project: 27927.04.001

	Initial Calibration Verification				Continuing Calibration Verification						
Analyte	True	Found	%Rec	Limit	True	Found1	%Rec	Found2	%Rec	Limit	M
Technetium-99	0.1	0.0993	99.3%	90%-110%	0.1	0.103	103.3%	0.0989	98.9%	90%-110%	MS2

Instruments/Methods (M)
MS2 - ICP-MS PE NexION/SW-846 Method 6020B
NA - Not Applicable

Form IIA-IN

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form IIA
Initial and Continuing Calibration Verification

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Result Units: ug/L
Associated Analytical Batches: 20230804-A003

SDG: 705610
SRR: 69648
Initial Calibration Source: See Raw Data
Continuing Calibration Source: See Raw Data

Case: 682609
Project: 27927.04.001

	Continuing Calibration Verification						
Analyte	True	Found3	%Rec	Found4	%Rec	Limit	M
Technetium-99	0.1	0.0990	99.0%	0.101	100.8%	90%-110%	MS2

Instruments/Methods (M)
MS2 - ICP-MS PE NexION/SW-846 Method 6020B
NA - Not Applicable

Form IIA-IN

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form IIA
Initial and Continuing Calibration Verification

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Result Units: ug/L
Associated Analytical Batches: 20230804-A004

SDG: 705610
SRR: 69648
Initial Calibration Source: See Raw Data
Continuing Calibration Source: See Raw Data

Case: 682609
Project: 27927.04.001

	Initial Calibration Verification				Continuing Calibration Verification						
Analyte	True	Found	%Rec	Limit	True	Found1	%Rec	Found2	%Rec	Limit	M
Technetium-99	0.1	0.0994	99.4%	90%-110%	0.1	0.100	100.2%	0.0997	99.7%	90%-110%	MS2

Instruments/Methods (M)
MS2 - ICP-MS PE NexION/SW-846 Method 6020B
NA - Not Applicable

Form IIA-IN

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form IIA
Initial and Continuing Calibration Verification

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Result Units: ug/L
Associated Analytical Batches: 20230804-A004

SDG: 705610
SRR: 69648
Initial Calibration Source: See Raw Data
Continuing Calibration Source: See Raw Data

Case: 682609
Project: 27927.04.001

	Continuing Calibration Verification						
Analyte	True	Found3	%Rec	Found4	%Rec	Limit	M
Technetium-99	0.1	0.0999	99.9%	0.0998	99.8%	90%-110%	MS2

Instruments/Methods (M)
MS2 - ICP-MS PE NexION/SW-846 Method 6020B
NA - Not Applicable

Form IIA-IN

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form IIB
Low Level Check Standard

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Result Units: ug/L
Associated Analytical Batch: 20230804-A003

SDG: 705610
SRR: 69648

Case: 682609
Project: 27927.04.001

	CRI/CRA Standards				
Analyte	True	Found1	%Rec	Limit	M
Technetium-99	0.005	0.00497	99.5%	80%-120%	MS2

Instruments/Methods (M)
MS2 - ICP-MS PE NexION/SW-846 Method 6020B
NA - Not Applicable

Form IIB-IN

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form IIB
Low Level Check Standard

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Result Units: ug/L
Associated Analytical Batch: 20230804-A004

SDG: 705610
SRR: 69648

Case: 682609
Project: 27927.04.001

	CRI/CRA Standards				
Analyte	True	Found1	%Rec	Limit	M
Technetium-99	0.005	0.00481	96.2%	80%-120%	MS2

Instruments/Methods (M)
MS2 - ICP-MS PE NexION/SW-846 Method 6020B
NA - Not Applicable

Form IIB-IN

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form III
Blanks

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Preparation Blank Result Units: mg/Kg
Initial/Continuing Blank Result Units: ug/L

SDG: 705610
SRR: 69648
Preparation Blank Matrix: Aqueous
Associated Prep Batches: 20230621-P015

Case: 682609
Project: 27927.04.001
Associated Analytical Batches: 20230804-A003

	Preparation Blank		Initial Calibration Blank		Continuing Calibration Blank								
Analyte	Result	Qual	Found	Qual	Found1	Qual	Found2	Qual	Found3	Qual	Found4	Qual	M
Technetium-99	0.00125	UD	0.00250	U	0.00250	U	0.00250	U	0.00250	U	0.00250	U	MS2

Data Reporting Qualifiers (Qual)	***Instruments/Methods (M)***
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	MS2 - ICP-MS PE NexION/SW-846 Method 6020B
U - Result is less than the Limit of Detection (LOD)	NA - Not Applicable
N - Matrix spike and/or matrix spike duplicate criteria was not met	
X - Analytical spike criteria was not met	
E - Result is estimated due to interferences	
D - Result is reported from a dilution	
* - Duplicate criteria was not met	

Form III-IN

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form III
Blanks

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Preparation Blank Result Units: mg/Kg
Initial/Continuing Blank Result Units: ug/L

SDG: 705610
SRR: 69648
Preparation Blank Matrix: Aqueous
Associated Prep Batches: 20230621-P015

Case: 682609
Project: 27927.04.001
Associated Analytical Batches: 20230804-A004

	Preparation Blank		Initial Calibration Blank		Continuing Calibration Blank								
Analyte	Result	Qual	Found	Qual	Found1	Qual	Found2	Qual	Found3	Qual	Found4	Qual	M
Technetium-99	-		0.00250	U	0.00250	U	0.00250	U	0.00250	U	0.00250	U	MS2

Data Reporting Qualifiers (Qual)	***Instruments/Methods (M)***
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	MS2 - ICP-MS PE NexION/SW-846 Method 6020B
U - Result is less than the Limit of Detection (LOD)	NA - Not Applicable
N - Matrix spike and/or matrix spike duplicate criteria was not met	
X - Analytical spike criteria was not met	
E - Result is estimated due to interferences	
D - Result is reported from a dilution	
* - Duplicate criteria was not met	

Form III-IN

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form IVB
ICP-MS Interference Check Sample

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Instrument: ICP-MS PE NexION
Result Units: ug/L

SDG: 705610
SRR: 69648
ICSA Source: See Raw Data
ICSB Source: See Raw Data

Case: 682609
Project: 27927.04.001, 27927.06.001
Analysis Date: 08/01/2023
Associated Analytical Batch: 20230804-A003

Analyte	True		Found				Limit	Limit
	Sol. ICSA	Sol. ICSAB	Sol. ICSA	%Rec	Sol. ICSAB	%Rec	ICSA	ICSAB
Technetium-99	0.006	0.026	0.00583	-	0.0284	109.1%	0.00100 to 0.0110	80%-120%

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form IVB
ICP-MS Interference Check Sample

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Instrument: ICP-MS PE NexION
Result Units: ug/L

SDG: 705610
SRR: 69648
ICSA Source: See Raw Data
ICSB Source: See Raw Data

Case: 682609
Project: 27927.04.001, 27927.06.001
Analysis Date: 08/01/2023
Associated Analytical Batch: 20230804-A004

Analyte	True		Found				Limit	Limit
	Sol. ICSA	Sol. ICSAB	Sol. ICSA	%Rec	Sol. ICSAB	%Rec	ICSA	ICSAB
Technetium-99	0.006	0.026	0.00687	-	0.0292	112.2%	0.00100 to 0.0110	80%-120%

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form VII

Laboratory Control Sample

SwRI ID
LCS23F21VG10

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: LCS23F21VG10
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Solid
Associated Prep Batches: 20230621-P015

Case: 682609
Project: 27927.04.001
LCS Source: NIST

Analyte	True	Found	Qual	%Rec.	Limit	M	Analysis Date/Time
Technetium-99	0.0292	0.0289	D	99.0%	80%-120%	MS2	08/01/2023 12:16

Instruments/Methods (M)

MS2 - ICP-MS PE NexION/SW-846 Method 6020B
NA - Not Applicable

Form VII-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form VII

Laboratory Control Sample

SwRI ID
LCS23F21VG9

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: LCS23F21VG9
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Solid
Associated Prep Batches: 20230621-P015

Case: 682609
Project: 27927.04.001
LCS Source: NIST

Analyte	True	Found	Qual	%Rec.	Limit	M	Analysis Date/Time
Technetium-99	0.0292	0.0291	D	99.7%	80%-120%	MS2	08/01/2023 12:13

Instruments/Methods (M)

MS2 - ICP-MS PE NexION/SW-846 Method 6020B
NA - Not Applicable

Form VII-IN

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form IX
Detection Limits

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Result Units: ug/L

SDG: 705610
SRR: 69648
Instrument: ICP-MS PE NexION

Case: 682609
Project:

Analyte	Mass	LOD	LOQ
Technetium-99	99	0.00250	0.00500

Columns

LOD - Limit of Detection
LOQ - Limit of Quantitation

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form XII
Analysis Run Log

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Analytical Batch: 20230804-A003
Analysis Method: SW-846 Method 6020B

SDG: 705610
SRR: 69648
Instrument: ICP-MS PE NexION

Case: 682609
Project: 27927.04.001
Start Date: 08/01/2023
End Date: 08/01/2023

Lab Sample ID	Client Sample ID	Time	DF	Tc99
S-0	S-0	11:38	1	X
S-250	S-250	11:41	1	X
ICV	ICV	11:44	1	X
ICB	ICB	11:46	1	X
CRI 1.0	CRI 1.0	11:49	1	
CRI 5.0	CRI 5.0	11:52	1	X
ICSA	ICSA	11:55	1	X
ICSAB	ICSAB	11:58	1	X
CCV	CCV	12:01	1	X
CCB	CCB	12:03	1	X
PB23F21VG3	NA	12:11	2	X
LCS23F21VG9	NA	12:13	2	X
LCS23F21VG10	NA	12:16	2	X
Z	Z	12:19	10	
Z	Z	12:22	1000	
CCV	CCV	12:25	1	X
CCB	CCB	12:28	1	X
PB23G28RN1	NA	12:37	5	
PB23G28RN2	NA	12:40	5	
LCS23G28RN1	NA	12:43	5	
LCS23G28RN2	NA	12:45	5	
Z	Z	12:48	1000	
Z	Z	12:51	1000	
Z	Z	12:54	5000	
Z	Z	12:57	1000	
Z	Z	13:00	1000	
Z	Z	13:02	1000	
CCV	CCV	13:05	1	X
CCB	CCB	13:08	1	X
Z	Z	13:11	1000	
Z	Z	13:14	1000	
Z	Z	13:17	1000	
Z	Z	13:20	1000	
Z	Z	13:22	1000	
Z	Z	13:25	1000	
Z	Z	13:28	1000	
Z	Z	13:31	1000	
Z	Z	13:34	1000	
Z	Z	13:37	1000	
CCV	CCV	13:39	1	X
CCB	CCB	13:42	1	X

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form XII
Analysis Run Log

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Analytical Batch: 20230804-A004
Analysis Method: SW-846 Method 6020B

SDG: 705610
SRR: 69648
Instrument: ICP-MS PE NexION

Case: 682609
Project: 27927.04.001
Start Date: 08/01/2023
End Date: 08/01/2023

Lab Sample ID	Client Sample ID	Time	DF	Tc99
S-0	S-0	16:05	1	X
S-250	S-250	16:08	1	X
ICV	ICV	16:11	1	X
ICB	ICB	16:14	1	X
CRI 1.0	CRI 1.0	16:16	1	
CRI 5.0	CRI 5.0	16:19	1	X
ICSA	ICSA	16:22	1	X
ICSAB	ICSAB	16:25	1	X
CCV	CCV	16:28	1	X
CCB	CCB	16:31	1	X
705610	TI147-EFF-Comp-A	16:40	100	X
705611	TI147-Feed-Comp-A	16:43	100	X
Z	Z	16:46	5000	
Z	Z	16:49	5000	
Z	Z	16:51	5000	
CCV	CCV	16:54	1	X
CCB	CCB	16:57	1	X
Z	Z	17:00	1000	
Z	Z	17:03	1000	
Z	Z	17:06	1000	
Z	Z	17:08	1000	
Z	Z	17:11	1000	
Z	Z	17:14	1000	
Z	Z	17:17	1000	
Z	Z	17:20	1000	
Z	Z	17:23	1000	
Z	Z	17:26	1000	
CCV	CCV	17:28	1	X
CCB	CCB	17:31	1	X
Z	Z	17:34	1000	
Z	Z	17:37	1000	
Z	Z	17:40	1000	
Z	Z	17:43	1000	
Z	Z	17:45	1000	
Z	Z	17:48	5000	
Z	Z	17:51	1000	
Z	Z	17:54	1000	
CCV	CCV	17:57	1	X
CCB	CCB	18:00	1	X

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form XVII
Linear Ranges

Client: Battelle Memorial Institute PNNL
Task Order:
Result Units: ug/L

SDG: 705610
SRR: 69648
Instrument: ICP-MS PE NexION

Case: 682609
Project: 27927.04.001, 27927.06.001
Date: 08/01/2023

Analyte	Upper Calibration Limit
Technetium-99	0.25

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form XVIII
Preparation/Digestion Summary

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2

SDG: 705610
SRR: 69648

Case: 682609
Project: 27927.04.001

Prep Batch	Method	Preparation Date
20230621-P015	Acid Dissolution	06/21/2023

Preparation Log

Metals

A34152

A34152

Southwest Research Institute
San Antonio, Texas 78238

Batch: 20230621-P015 (Ver. 1)
Status: APPROVED

Client(s): Battelle Memorial Institute PNNL
Task Order(s): 230526-2
SDG(s): 705610
Case(s): 682609
Project(s): 27927.04
Method(s): Acid Dissolution (TAP: 01-0406-037)
Matrix(s): Aqueous
Instrument(s): ICP-MS
Reagent(s): HNO3 237025
Balance(s): Bal #88 (AN:014981)
Pipette(s): 5000-18, 1000-J, 200-1
Equipment: CT 20230621-Q005
Heating Device: ModBlock#1
Temperature (C): 95
Time In: 06/21/2023 13:38:12 Time Out: 06/21/2023 14:08:23
Location: S12-B12

Sample Identification	Client Identification	Weight (g)	Final Volume (mL)
PB23F21VG3	NA	0.1000	25
LCS23F21VG9 ①	NA	0.1000	25
LCS23F21VG10 ①	NA	0.1000	25
705610	TI147-EFF-Comp-A	0.1070	25
705611	TI147-Feed-Comp-A	0.1139	25

① spiked 0.1 mL of CI# 94145 Technetium-99 002RadSol4 (Lot# SRM4288A, Source: NIST, Exp: 03/01/2024)

Comments:
Limited sample omitted Dup and MS (Rad)

Procedure:
See TAP 01-0406-037 for details.

CGL - 08/09/2023

Prepared by: GOMEZ, VANESSA Date: 06/21/2023

Reviewed by: RANGER, JACQUELINE Date: 07/17/2023

Disposal Int/Date/Loc: _____

SOUTHWEST RESEARCH INSTITUTE
CLIENT: Battelle Memorial Institute PNNL
SwRI Project #: 27927.04.001
SwRI Task Order #: 230526-2
SDG #: 705610
TA #: 682609

CESIUM RESULTS

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2

SDG: 705610
SRR: 69648

Case: 682609
Project: 27927.04.001

Client Sample ID	Lab Sample ID
TI147-EFF-Comp-A	705610
TI147-Feed-Comp-A	705611
TI147-L-16-A	705612
TI147-L-18-A	705613
TI147-L-20-A	705614
TI147-L-22-A	705615
TI147-L-24-A	705616
TI147-L-26-A	705617
TI147-P-14-A	705618
TI147-P-16-A	705619
TI147-P-18-A	705620
TI147-P-20-A	705621

Comments:

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI147-EFF-Comp-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705610
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7440-46-2	Cesium	0.0444	UD	MS1	0.0444	0.0889	10	20230621-P014	07/31/2023 14:00

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	MS1 - ICP-MS PE DRC II/SW-846 Method 6020B
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	NA - Not Applicable
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI147-Feed-Comp-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705611
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7440-46-2	Cesium	1.03	D	MS1	0.0440	0.0880	10	20230621-P014	07/31/2023 14:03

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	MS1 - ICP-MS PE DRC II/SW-846 Method 6020B
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	NA - Not Applicable
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI47-L-16-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705612
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7440-46-2	Cesium	0.0441	UD	MS1	0.0441	0.0882	10	20230621-P014	07/31/2023 14:10

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	MS1 - ICP-MS PE DRC II/SW-846 Method 6020B
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	NA - Not Applicable
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI147-L-18-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705613
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7440-46-2	Cesium	0.0451	UD	MS1	0.0451	0.0902	10	20230621-P014	07/31/2023 14:17

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	MS1 - ICP-MS PE DRC II/SW-846 Method 6020B
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	NA - Not Applicable
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
TI147-L-20-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705614
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7440-46-2	Cesium	0.0446	UD	MS1	0.0446	0.0891	10	20230621-P014	07/31/2023 14:20

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	MS1 - ICP-MS PE DRC II/SW-846 Method 6020B
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	NA - Not Applicable
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form I
Certificate of Analysis

Client Sample ID
T147-L-22-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705615
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7440-46-2	Cesium	0.0442	UD	MS1	0.0442	0.0883	10	20230621-P014	07/31/2023 14:23

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	MS1 - ICP-MS PE DRC II/SW-846 Method 6020B
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	NA - Not Applicable
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
T147-L-24-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705616
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7440-46-2	Cesium	0.0446	UD	MS1	0.0446	0.0891	10	20230621-P014	07/31/2023 14:25

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	MS1 - ICP-MS PE DRC II/SW-846 Method 6020B
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	NA - Not Applicable
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
T147-L-26-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705617
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7440-46-2	Cesium	0.0443	UD	MS1	0.0443	0.0886	10	20230621-P014	07/31/2023 14:28

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	MS1 - ICP-MS PE DRC II/SW-846 Method 6020B
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	NA - Not Applicable
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
T147-P-14-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705618
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7440-46-2	Cesium	0.0442	UD	MS1	0.0442	0.0883	10	20230621-P014	07/31/2023 14:30

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	MS1 - ICP-MS PE DRC II/SW-846 Method 6020B
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	NA - Not Applicable
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form I
Certificate of Analysis

Client Sample ID
T147-P-16-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705619
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7440-46-2	Cesium	0.0447	UD	MS1	0.0447	0.0894	10	20230621-P014	07/31/2023 14:33

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	MS1 - ICP-MS PE DRC II/SW-846 Method 6020B
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	NA - Not Applicable
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
T147-P-18-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705620
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7440-46-2	Cesium	0.0445	UD	MS1	0.0445	0.0889	10	20230621-P014	07/31/2023 14:35

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	MS1 - ICP-MS PE DRC II/SW-846 Method 6020B
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	NA - Not Applicable
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form I

Certificate of Analysis

Client Sample ID
T147-P-20-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705621
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7440-46-2	Cesium	0.0442	UD	MS1	0.0442	0.0883	10	20230621-P014	07/31/2023 14:37

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	MS1 - ICP-MS PE DRC II/SW-846 Method 6020B
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	NA - Not Applicable
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form I
Certificate of Analysis

SwRI ID
PB23F21VG2
Type: Blank

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: PB23F21VG2
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Solid
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: NA
Collection Date: NA

CAS No.	Analyte	Result	Qual	M	LOD	LOQ	DF	Prep Batch	Analysis Date/Time
7440-46-2	Cesium	0.0500	UD	MS1	0.0500	0.100	10	20230621-P014	07/31/2023 13:48

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	LOD - Limit of Detection	MS1 - ICP-MS PE DRC II/SW-846 Method 6020B
U - Result is less than the Limit of Detection (LOD)	LOQ - Limit of Quantitation	NA - Not Applicable
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	
X - Analytical spike criteria was not met	M - Instrument	
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form IIA
Initial and Continuing Calibration Verification

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Result Units: ug/L
Associated Analytical Batches: 20230804-A002

SDG: 705610
SRR: 69648
Initial Calibration Source: See Raw Data
Continuing Calibration Source: See Raw Data

Case: 682609
Project: 27927.04.001

	Initial Calibration Verification				Continuing Calibration Verification						
Analyte	True	Found	%Rec	Limit	True	Found1	%Rec	Found2	%Rec	Limit	M
Cesium	40	39.8	99.6%	90%-110%	40	39.1	97.8%	39.2	98.0%	90%-110%	MS1

Instruments/Methods (M)

MS1 - ICP-MS PE DRC II/SW-846 Method 6020B
NA - Not Applicable

Form IIA-IN

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form IIA
Initial and Continuing Calibration Verification

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Result Units: ug/L
Associated Analytical Batches: 20230804-A002

SDG: 705610
SRR: 69648
Initial Calibration Source: See Raw Data
Continuing Calibration Source: See Raw Data

Case: 682609
Project: 27927.04.001

	Continuing Calibration Verification				
Analyte	True	Found3	%Rec	Limit	M
Cesium	40	39.3	98.1%	90%-110%	MS1

Instruments/Methods (M)
MS1 - ICP-MS PE DRC II/SW-846 Method 6020B
NA - Not Applicable

Form IIA-IN

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form IIB
Low Level Check Standard

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Result Units: ug/L
Associated Analytical Batch: 20230804-A002

SDG: 705610
SRR: 69648

Case: 682609
Project: 27927.04.001

	CRI/CRA Standards				
Analyte	True	Found1	%Rec	Limit	M
Cesium	0.1	0.0960	96.0%	80%-120%	MS1

Instruments/Methods (M)
MS1 - ICP-MS PE DRC II/SW-846 Method 6020B
NA - Not Applicable

Form IIB-IN

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form III
Blanks

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Preparation Blank Result Units: mg/Kg
Initial/Continuing Blank Result Units: ug/L

SDG: 705610
SRR: 69648
Preparation Blank Matrix: Aqueous
Associated Prep Batches: 20230621-P014

Case: 682609
Project: 27927.04.001
Associated Analytical Batches: 20230804-A002

	Preparation Blank		Initial Calibration Blank		Continuing Calibration Blank						
Analyte	Result	Qual	Found	Qual	Found1	Qual	Found2	Qual	Found3	Qual	M
Cesium	0.0500	UD	0.0500	U	0.0500	U	0.0500	U	0.0500	U	MS1

Data Reporting Qualifiers (Qual)	***Instruments/Methods (M)***
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	MS1 - ICP-MS PE DRC II/SW-846 Method 6020B
U - Result is less than the Limit of Detection (LOD)	NA - Not Applicable
N - Matrix spike and/or matrix spike duplicate criteria was not met	
X - Analytical spike criteria was not met	
E - Result is estimated due to interferences	
D - Result is reported from a dilution	
* - Duplicate criteria was not met	

Form III-IN

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form IVB
ICP-MS Interference Check Sample

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Instrument: ICP-MS PE DRC II
Result Units: ug/L

SDG: 705610
SRR: 69648
ICSA Source: See Raw Data
ICSB Source: See Raw Data

Case: 682609
Project: 27927.04.001
Analysis Date: 07/31/2023
Associated Analytical Batch: 20230804-A002

Analyte	True		Found				Limit	Limit
	Sol. ICSA	Sol. ICSAB	Sol. ICSA	%Rec	Sol. ICSAB	%Rec	ICSA	ICSAB
Cesium	0.02	20.02	0.0811	-	20.3	101.6%	-0.0800 to 0.120	80%-120%

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form VB
Post-Digestion Spike Sample Recovery

Client Sample ID
TI147-Feed-Comp-AAS

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705611AS
Result Units: ug/L

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001

Analyte	Parent Sample Result	Qual	Spiked Sample Result	Qual	Spike Added	%Rec.	Control Limit	M	Q	DF	Prep Batch	Analysis Date/Time	Note
Cesium	1.16	D	21.4	D	20	101.4%	80%-120%	MS1		10	20230621-P014	07/31/2023 14:08	

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	M - Instrument	MS1 - ICP-MS PE DRC II/SW-846 Method 6020B
U - Result is less than the Limit of Detection (LOD)	MS - Matrix Spike	NA - Not Applicable
N - Matrix spike and/or matrix spike duplicate criteria was not met	MSD - Matrix Spike Duplicate	
X - Analytical spike criteria was not met	Q - Qualifier	
E - Result is estimated due to interferences	RPD - Relative Percent Difference	
D - Result is reported from a dilution		
* - Duplicate criteria was not met		

Form VB-IN

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form VII
Laboratory Control Sample

SwRI ID
LCS23F21VG7

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: LCS23F21VG7
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Solid
Associated Prep Batches: 20230621-P014

Case: 682609
Project: 27927.04.001
LCS Source: Inorganic Ventures

Analyte	True	Found	Qual	%Rec.	Limit	M	Analysis Date/Time
Cesium	10.0	8.97	D	89.7%	80%-120%	MS1	07/31/2023 13:55

Instruments/Methods (M)

MS1 - ICP-MS PE DRC II/SW-846 Method 6020B
NA - Not Applicable

Form VII-IN

SOUTHWEST RESEARCH INSTITUTE

Metals Report - Form VII

Laboratory Control Sample

SwRI ID
LCS23F21VG8

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: LCS23F21VG8
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Solid
Associated Prep Batches: 20230621-P014

Case: 682609
Project: 27927.04.001
LCS Source: Inorganic Ventures

Analyte	True	Found	Qual	%Rec.	Limit	M	Analysis Date/Time
Cesium	10.0	8.91	D	89.1%	80%-120%	MS1	07/31/2023 13:58

Instruments/Methods (M)

MS1 - ICP-MS PE DRC II/SW-846 Method 6020B
NA - Not Applicable

Form VII-IN

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form VIII
ICP-AES and ICP-MS Serial Dilutions

Client Sample ID
Tr147-Feed-Comp-AL

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705611L
Result Units: ug/L

SDG: 705610
SRR: 69648
Matrix: Aqueous

Case: 682609
Project: 27927.04.001

Analyte	Parent Sample Result	Qual	Serial Dilution Result	Qual	% Diff.	% Diff. Limit	M	Note	DF	Prep Batch	Analysis Date/Time
Cesium	1.16	D	1.16	D	0.388%	-	MS1	#	50	20230621-P014	07/31/2023 14:05

# Indicates that the parent sample result is less than 50 times the LOD, therefore no percent difference limit is applicable.

Data Reporting Qualifiers (Qual)	***Instruments/Methods (M)***
J - Result is greater than or equal to the Limit of Detection (LOD) and less than the Limit of Quantitation (LOQ)	MS1 - ICP-MS PE DRC II/SW-846 Method 6020B
U - Result is less than the Limit of Detection (LOD))	NA - Not Applicable
N - Matrix spike and/or matrix spike duplicate criteria was not met	
X - Analytical spike criteria was not met	
E - Result is estimated due to interferences	
D - Result is reported from a dilution	
* - Duplicate criteria was not met	

Form VIII-IN

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form IX
Detection Limits

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Result Units: ug/L

SDG: 705610
SRR: 69648
Instrument: ICP-MS PE DRC II

Case: 682609
Project: 27927.04.001

Analyte	Mass	LOD	LOQ
Cesium	133	0.0500	0.100

Columns	
LOD	- Limit of Detection
LOQ	- Limit of Quantitation

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form XII
Analysis Run Log

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Analytical Batch: 20230804-A002
Analysis Method: SW-846 Method 6020B

SDG: 705610
SRR: 69648
Instrument: ICP-MS PE DRC II

Case: 682609
Project: 27927.04.001
Start Date: 07/31/2023
End Date: 07/31/2023

Lab Sample ID	Client Sample ID	Time	DF	Cs133
S-0	S-0	13:23	1	X
S-100	S-100	13:25	1	X
ICV	ICV	13:28	1	X
ICB	ICB	13:30	1	X
CRI 0.1	CRI 0.1	13:33	1	X
ICSA	ICSA	13:35	1	X
ICSAB	ICSAB	13:38	1	X
ZZZZZ	ZZZZZ	13:40	1	
CCV	CCV	13:43	1	X
CCB	CCB	13:45	1	X
PB23F21VG2	NA	13:48	10	X
LCS23F21VG5	NA	13:50	10	
LCS23F21VG6	NA	13:53	10	
LCS23F21VG7	NA	13:55	10	X
LCS23F21VG8	NA	13:58	10	X
705610	TI147-EFF-Comp-A	14:00	10	X
705611	TI147-Feed-Comp-A	14:03	10	X
705611L	TI147-Feed-Comp-AL	14:05	50	X
705611A	TI147-Feed-Comp-AAS	14:08	10	X
705612	TI147-L-16-A	14:10	10	X
CCV	CCV	14:13	1	X
CCB	CCB	14:15	1	X
705613	TI147-L-18-A	14:17	10	X
705614	TI147-L-20-A	14:20	10	X
705615	TI147-L-22-A	14:23	10	X
705616	TI147-L-24-A	14:25	10	X
705617	TI147-L-26-A	14:28	10	X
705618	TI147-P-14-A	14:30	10	X
705619	TI147-P-16-A	14:33	10	X
705620	TI147-P-18-A	14:35	10	X
705621	TI147-P-20-A	14:37	10	X
CCV	CCV	14:40	1	X
CCB	CCB	14:42	1	X

Linear Ranges

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Result Units: ug/L

SDG: 705610
SRR: 69648
Instrument: ICP-MS PE DRC II

Case: 682609
Project: 27927.04.001
Date: 07/31/2023

Analyte	Upper Calibration Limit
Cesium	100

SOUTHWEST RESEARCH INSTITUTE
Metals Report - Form XVIII
Preparation/Digestion Summary

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2

SDG: 705610
SRR: 69648

Case: 682609
Project: 27927.04.001

Prep Batch	Method	Preparation Date
20230621-P014	Acid Dissolution	06/21/2023

Preparation Log

Metals

A34151

A34151

Southwest Research Institute
San Antonio, Texas 78238

Batch: 20230621-P014 (Ver. 1)
Status: APPROVED

Client(s): Battelle Memorial Institute PNNL
Task Order(s): 230526-2
SDG(s): 705610
Case(s): 682609
Project(s): 27927.04
Method(s): Acid Dissolution (TAP: 01-0406-037)
Matrix(s): Aqueous
Instrument(s): ICP, ICP-MS
Reagent(s): HCl 237024
Balance(s): Bal #88 (AN:014981)
Pipette(s): 1000-J, 200-1
Equipment: CT 20230621-Q005
Heating Device: ModBlock#1
Temperature (C): 95
Time In: 06/21/2023 13:38:45 Time Out: 06/21/2023 14:08:49
Location: S12-B12

Sample Identification	Client Identification	Weight (g)	Final Volume (mL)
PB23F21VG2	NA	0.5000	50
LCS23F21VG5 ①	NA	0.5000	50
LCS23F21VG6 ①	NA	0.5000	50
LCS23F21VG7 ②	NA	0.5000	50
LCS23F21VG8 ②	NA	0.5000	50
705610	TI147-EFF-Comp-A	0.5627	50
705611	TI147-Feed-Comp-A	0.5679	50
705612	TI147-L-16-A	0.5670	50
705613	TI147-L-18-A	0.5545	50
705614	TI147-L-20-A	0.5609	50
705615	TI147-L-22-A	0.5661	50
705616	TI147-L-24-A	0.5611	50
705617	TI147-L-26-A	0.5642	50
705618	TI147-P-14-A	0.5662	50
705619	TI147-P-16-A	0.5590	50
705620	TI147-P-18-A	0.5622	50
705621	TI147-P-20-A	0.5662	50

CGL - 08/09/2023

Prepared by: GOMEZ, VANESSA Date: 06/21/2023

Reviewed by: RANGER, JACQUELINE Date: 07/17/2023

Disposal Int/Date/Loc:

Preparation Log

Metals

A34151
A34151

Southwest Research Institute
San Antonio, Texas 78238

Batch: 20230621-P014 (Ver. 1)
Status: APPROVED

Client(s): Battelle Memorial Institute PNNL
Task Order(s): 230526-2
SDG(s): 705610
Case(s): 682609
Project(s): 27927.04
Method(s): Acid Dissolution (TAP: 01-0406-037)
Matrix(s): Aqueous
Instrument(s): ICP, ICP-MS
Reagent(s): HCl 237024
Balance(s): Bal #88 (AN:014981)
Pipette(s): 1000-J, 200-1
Equipment: CT 20230621-Q005
Heating Device: ModBlock#1
Temperature (C): 95
Time In: 06/21/2023 13:38:45 Time Out: 06/21/2023 14:08:49
Location: S12-B12

Sample Identification	Client Identification	Weight (g)	Final Volume (mL)

① spiked 0.1 mL of CI# 222930 Bismuth (Lot# T2-Bi717219, Source: Inorganic Ventures, Exp: 11/15/2023) and
0.1 mL of CI# 216944 Boron (Lot# S2-B709783, Source: Inorganic Ventures, Exp: 08/19/2023) and
0.2 mL of CI# 231412 Instrument Calibration Standard 1 (Lot# 58-237CRY, Source: Spex Certiprep, Exp: 04/30/2024) and
0.1 mL of CI# 222935 Phosphorus (Lot# T2-P718589, Source: Inorganic Ventures, Exp: 11/15/2023) and
0.1 mL of CI# 232592 Silicon (Lot# T2-Si719534, Source: Inorganic Ventures, Exp: 04/27/2024) and
0.5 mL of CI# 213208 Spike Sample Standard I (Lot# 57-046CRX, Source: Spex Certiprep, Exp: 06/30/2023) and
0.1 mL of CI# 216948 Sulfur (Lot# S2-S707422, Source: Inorganic Ventures, Exp: 08/19/2023) and
0.1 mL of CI# 216950 Titanium (Lot# T2-Ti719972, Source: Inorganic Ventures, Exp: 08/19/2023) and
0.1 mL of CI# 216951 Uranium (Lot# S2-U707914, Source: Inorganic Ventures, Exp: 08/19/2023) and
0.1 mL of CI# 232595 Zirconium (Lot# T2-ZR720306, Source: Inorganic Ventures, Exp: 04/27/2024)

② spiked 0.05 mL of CI# 227236 CCS-1 (Lot# T2-MEB716964, Source: Inorganic Ventures, Exp: 01/27/2024) and
0.05 mL of CI# 227237 CCS-2 (Lot# T2-MEB725290, Source: Inorganic Ventures, Exp: 01/27/2024) and
0.05 mL of CI# 227239 CCS-4 (Lot# T2-MEB719528, Source: Inorganic Ventures, Exp: 01/27/2024) and
0.05 mL of CI# 227240 CCS-5 (Lot# S2-MEB709512, Source: Inorganic Ventures, Exp: 01/27/2024) and
0.05 mL of CI# 227241 CCS-6 (Lot# T2-MEB721700, Source: Inorganic Ventures, Exp: 01/27/2024) and
0.05 mL of CI# 227238 Tellurium (Lot# T2-TE715844, Source: Inorganic Ventures, Exp: 01/27/2024)

Comments:
Limited sample omitted Dup and MS

Procedure:
See TAP 01-0406-037 for details.

CGL - 08/09/2023

Prepared by: GOMEZ, VANESSA Date: 06/21/2023

Reviewed by: RANGER, JACQUELINE Date: 07/17/2023

Disposal Int/Date/Loc: _____

Test Report

SwRI Project #:	27927.04.001
SwRI SDG:	705610
SwRI Task Order:	230526-2
SwRI Sample Receipt:	69648
Date Received:	05/18/2023

Purchase Order #: 682609
TIC & TOC Report

Prepared by:
Southwest Research Institute®
Department of Analytical and Environmental Chemistry
6220 Culebra Road
San Antonio, Texas 78238

Prepared for:
Battelle Memorial Institute - PNNL
902 Battelle Boulevard
P.O. Box 999
Richland, WA 99354
Attn: Ms. Amy Westesen

Authorized for Release
07/21/2023 5:00PM
Jackie Ranger, Project Manager
jacqueline.ranger@swri.org
210-522-3320

Mike Dammann
Laboratory Director

SOUTHWEST RESEARCH INSTITUTE
CLIENT: Battelle Memorial Institute PNNL
SwRI Project #: 27927.04.001
SwRI Task Order #: 230526-2
SDG #: 705610
TA #: 682609

CASE NARRATIVE

Client: Battelle Memorial Institute PNNL
SDG: 705610
SwRI Project Number: 27927.04.001
SwRI Task Order Number(s): 230526-2

Total Inorganic Carbon & Total Organic Carbon

The liquid samples were diluted by weight and analyzed on the Phoenix 8000 for total inorganic carbon and total organic carbon in accordance with SwRI TAP 01-0406-159 (SW-846 9060M). The sample results were reported on a weight basis. Sample TI147-EFF-Comp-A (705610) was analyzed in duplicate and spiked. Carbonate results were calculated by multiplying the TIC results by 5.

QC:

All PBs, ICB's and CCB's were less than the reporting limit. All LCS's, ICV's and CCV's were within 90-110% recovery. All duplicates were within 20% RPD. All matrix spike recoveries were within 80-120%.

James Moken Digitally signed by James Moken Date: 2023.06.29 16:24:22 -05'00'

Prepared By

SOUTHWEST RESEARCH INSTITUTE
CLIENT: Battelle Memorial Institute PNNL
SwRI Project #: 27927.04.001
SwRI Task Order #: 230526-2
SDG #: 705610
TA #: 682609

TIC & TOC RESULTS

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2

SDG: 705610
SRR: 69648

Case: 682609
Project: 27927.04.001

Client Sample ID	Lab Sample ID
TI147-EFF-Comp-A	705610
TI147-EFF-Comp-AD	705610D
TI147-Feed-Comp-A	705611

Comments:

SOUTHWEST RESEARCH INSTITUTE

WetChem Report - Form I

Certificate of Analysis

Client Sample ID
TI147-EFF-Comp-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705610
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	RL	DF	Prep Batch	Analysis Date/Time
NA	Total Inorganic Carbon	2,940	D	Pnx	533	10	20230623-P002	06/05/2023 14:36
NA	Total Organic Carbon	828		Pnx	53.2	1	20230623-P003	06/15/2023 19:17
NA	Carbonate	14,700	D	Pnx	2,670	10	20230623-P002	06/05/2023 14:36

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
U - Result is less than the SwRI Reporting Limit (RL)	RL - SwRI Reporting Limit	Pnx - Phoenix 8000 TOC analyzer/TIC by 9060M
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	Pnx - Phoenix 8000 TOC analyzer/TOC 9060M
X - Analytical spike criteria was not met	M - Instrument	NA - Not Applicable
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

WetChem Report - Form I

Certificate of Analysis

Client Sample ID
TI147-Feed-Comp-A
Type: Unknown

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705611
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: 05/18/2023
Collection Date: 05/11/2023

CAS No.	Analyte	Result	Qual	M	RL	DF	Prep Batch	Analysis Date/Time
NA	Total Inorganic Carbon	3,300	D	Pnx	531	10	20230623-P002	06/05/2023 14:59
NA	Total Organic Carbon	864		Pnx	53.1	1	20230623-P003	06/15/2023 19:31
NA	Carbonate	16,500	D	Pnx	2,650	10	20230623-P002	06/05/2023 14:59

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
U - Result is less than the SwRI Reporting Limit (RL)	RL - SwRI Reporting Limit	Pnx - Phoenix 8000 TOC analyzer/TIC by 9060M
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	Pnx - Phoenix 8000 TOC analyzer/TOC 9060M
X - Analytical spike criteria was not met	M - Instrument	NA - Not Applicable
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE

WetChem Report - Form I

Certificate of Analysis

SwRI ID
ICB
Type: ICB/Blank

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: ICB
Result Units: mg/L

SDG: 705610
SRR: 69648
Matrix: Water
% Solids: NA

Case: 682609
Project: 27927.04.001
Receipt Date: NA
Collection Date: NA

CAS No.	Analyte	Result	Qual	M	RL	DF	Prep Batch	Analysis Date/Time
NA	Total Inorganic Carbon	0.200	U	Pnx	0.200	1	NA	06/05/2023 10:41
NA	Total Organic Carbon	0.200	U	Pnx	0.200	1	NA	06/15/2023 00:09
NA	Carbonate	1.00	U	Pnx	1.00	1	NA	06/05/2023 10:41

Data Reporting Qualifiers (Qual)	*Columns*	*Instruments/Methods (M)*
U - Result is less than the SwRI Reporting Limit (RL)	RL - SwRI Reporting Limit	Pnx - Phoenix 8000 TOC analyzer/TIC by 9060M
N - Matrix spike and/or matrix spike duplicate criteria was not met	DF - Dilution Factor	Pnx - Phoenix 8000 TOC analyzer/TOC 9060M
X - Analytical spike criteria was not met	M - Instrument	NA - Not Applicable
E - Result is estimated due to interferences		
D - Result is reported from a dilution		
* - Duplicate criteria was not met		
& - See narrative		

Form I-IN

SOUTHWEST RESEARCH INSTITUTE
WetChem Report - Form IIA
Initial and Continuing Calibration Verification

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Result Units: mg/L
Associated Analytical Batches: 20230623-A001

SDG: 705610
SRR: 69648
Initial Calibration Source: See Raw Data
Continuing Calibration Source: See Raw Data

Case: 682609
Project: 27927.04.001

	Initial Calibration Verification				Continuing Calibration Verification						
Analyte	True	Found	%Rec	Limit	True	Found1	%Rec	Found2	%Rec	Limit	M
Total Inorganic Carbon	2.50	2.43	97.2%	90%-110%	2.50	2.40	96.0%	2.44	97.6%	90%-110%	Pnx

Instruments/Methods (M)

Pnx - Phoenix 8000 TOC analyzer/TIC by 9060M
Pnx - Phoenix 8000 TOC analyzer/TOC 9060M
NA - Not Applicable

Form IIA-IN

SOUTHWEST RESEARCH INSTITUTE
WetChem Report - Form IIA
Initial and Continuing Calibration Verification

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Result Units: mg/L
Associated Analytical Batches: 20230623-A001

SDG: 705610
SRR: 69648
Initial Calibration Source: See Raw Data
Continuing Calibration Source: See Raw Data

Case: 682609
Project: 27927.04.001

	Continuing Calibration Verification						
Analyte	True	Found3	%Rec	Found4	%Rec	Limit	M
Total Inorganic Carbon	2.50	2.52	100.8%	2.48	99.2%	90%-110%	Pnx

Instruments/Methods (M)

Pnx - Phoenix 8000 TOC analyzer/TIC by 9060M
Pnx - Phoenix 8000 TOC analyzer/TOC 9060M
NA - Not Applicable

Form IIA-IN

SOUTHWEST RESEARCH INSTITUTE
WetChem Report - Form IIA
Initial and Continuing Calibration Verification

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Result Units: mg/L
Associated Analytical Batches: 20230623-A002

SDG: 705610
SRR: 69648
Initial Calibration Source: Agilent
Continuing Calibration Source: Agilent

Case: 682609
Project: 27927.04.001

	Initial Calibration Verification				Continuing Calibration Verification						
Analyte	True	Found	%Rec	Limit	True	Found1	%Rec	Found2	%Rec	Limit	M
Total Organic Carbon	2.50	2.44	97.6%	90%-110%	2.50	2.44	97.6%	2.45	98.0%	90%-110%	Pnx

Instruments/Methods (M)
Pnx - Phoenix 8000 TOC analyzer/TIC by 9060M
Pnx - Phoenix 8000 TOC analyzer/TOC 9060M
NA - Not Applicable

Form IIA-IN

SOUTHWEST RESEARCH INSTITUTE
WetChem Report - Form IIA
Initial and Continuing Calibration Verification

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Result Units: mg/L
Associated Analytical Batches: 20230623-A002

SDG: 705610
SRR: 69648
Initial Calibration Source: Agilent
Continuing Calibration Source: Agilent

Case: 682609
Project: 27927.04.001

	Continuing Calibration Verification								
Analyte	True	Found3	%Rec	Found4	%Rec	Found5	%Rec	Limit	M
Total Organic Carbon	2.50	2.44	97.6%	2.36	94.4%	2.36	94.4%	90%-110%	Pnx

Instruments/Methods (M)
Pnx - Phoenix 8000 TOC analyzer/TIC by 9060M
Pnx - Phoenix 8000 TOC analyzer/TOC 9060M
NA - Not Applicable

Form IIA-IN

SOUTHWEST RESEARCH INSTITUTE
WetChem Report - Form III
Blanks

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Preparation Blank Result Units: mg/L
Initial/Continuing Blank Result Units: mg/L

SDG: 705610
SRR: 69648
Preparation Blank Matrix: Aqueous
Associated Prep Batches: 20230623-P002

Case: 682609
Project: 27927.04.001
Associated Analytical Batches: 20230623-A001

	Preparation Blank		Initial Calibration Blank		Continuing Calibration Blank								
Analyte	Result	Qual	Found	Qual	Found1	Qual	Found2	Qual	Found3	Qual	Found4	Qual	M
Total Inorganic Carbon	0.200	U	0.200	U	0.200	U	0.200	U	0.200	U	0.200	U	Pnx

Data Reporting Qualifiers (Qual)	*Instruments/Methods (M)*
U - Result is less than the SwRI Reporting Limit (RL)	Pnx - Phoenix 8000 TOC analyzer/TIC by 9060M
N - Matrix spike and/or matrix spike duplicate criteria was not met	Pnx - Phoenix 8000 TOC analyzer/TOC 9060M
X - Analytical spike criteria was not met	NA - Not Applicable
E - Result is estimated due to interferences	
D - Result is reported from a dilution	
* - Duplicate criteria was not met	

Form III-IN

SOUTHWEST RESEARCH INSTITUTE
WetChem Report - Form III
Blanks

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Preparation Blank Result Units: mg/L
Initial/Continuing Blank Result Units: mg/L

SDG: 705610
SRR: 69648
Preparation Blank Matrix: Aqueous
Associated Prep Batches: 20230623-P003

Case: 682609
Project: 27927.04.001
Associated Analytical Batches: 20230623-A002

	Preparation Blank		Initial Calibration Blank		Continuing Calibration Blank										
Analyte	Result	Qual	Found	Qual	Found1	Qual	Found2	Qual	Found3	Qual	Found4	Qual	Found5	Qual	M
Total Organic Carbon	0.200	U	0.200	U	0.200	U	0.200	U	0.200	U	0.200	U	0.200	U	Pnx

Data Reporting Qualifiers (Qual)	***Instruments/Methods (M)***
U - Result is less than the SwRI Reporting Limit (RL)	Pnx - Phoenix 8000 TOC analyzer/TIC by 9060M
N - Matrix spike and/or matrix spike duplicate criteria was not met	Pnx - Phoenix 8000 TOC analyzer/TOC 9060M
X - Analytical spike criteria was not met	NA - Not Applicable
E - Result is estimated due to interferences	
D - Result is reported from a dilution	
* - Duplicate criteria was not met	

Form III-IN

SOUTHWEST RESEARCH INSTITUTE
WetChem Report - Form VA

Client Sample ID
TI147-EFF-Comp-AMS

Matrix Spike/Matrix Spike Duplicate Sample Recovery

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705610MS
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001

Analyte	Parent Sample Result	Qual	MS Result	MS Spike Added	MS %Rec	MSD Result	MSD Spike Added	MSD %Rec	%RPD	Control Limit %Rec	Control Limit %RPD	M	Note
Total Inorganic Carbon	2940	D	7200	4440	95.9%	-	-	-	-	80%-120%	-	Pnx	
Total Organic Carbon	828		1460	648	97.5%	-	-	-	-	80%-120%	-	Pnx	
Carbonate	14,700	D	36,000	22,200	95.9%	-	-	-	-	80%-120%	-	Pnx	

Data Reporting Qualifiers (Qual)	***Columns***	***Instruments/Methods (M)***
U - Result is less than the SwRI Reporting Limit (RL)	M - Instrument	Pnx - Phoenix 8000 TOC analyzer/TIC by 9060M
N - Matrix spike and/or matrix spike duplicate criteria was not met	MS - Matrix Spike	Pnx - Phoenix 8000 TOC analyzer/TOC 9060M
X - Analytical spike criteria was not met	MSD - Matrix Spike Duplicate	NA - Not Applicable
E - Result is estimated due to interferences	Q - Qualifier	
D - Result is reported from a dilution	RPD - Relative Percent Difference	
* - Duplicate criteria was not met		

Form VA-IN

SOUTHWEST RESEARCH INSTITUTE
WetChem Report - Form VI
Duplicates

Client Sample ID
TI147-EFF-Comp-AD

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: 705610D
Result Units: mg/Kg

SDG: 705610
SRR: 69648
Matrix: Aqueous
% Solids: NA

Case: 682609
Project: 27927.04.001

Analyte	Parent Sample Result	Qual	Duplicate Result	Qual	RPD	RPD Limit	Control Limit	M	Note
Total Inorganic Carbon	2940	D	2930	D	0.341%	20%	-	Pnx	
Total Organic Carbon	828		830		0.241%	20%	-	Pnx	
Carbonate	14,700	D	14,700	D	0.000%	20%	-	Pnx	

Data Reporting Qualifiers (Qual)	***Columns***	***Instruments/Method (M)***
U - Result is less than the SwRI Reporting Limit (RL) N - Matrix spike and/or matrix spike duplicate criteria was not met X - Analytical spike criteria was not met E - Result is estimated due to interferences D - Result is reported from a dilution * - Duplicate criteria was not met	M - Instrument RPD - Relative Percent Difference	Pnx - Phoenix 8000 TOC analyzer/TIC by 9060M Pnx - Phoenix 8000 TOC analyzer/TOC 9060M NA - Not Applicable

Form VI-IN

SOUTHWEST RESEARCH INSTITUTE

WetChem Report - Form VII

Laboratory Control Sample

SwRI ID
ICV

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Lab ID: ICV
Result Units: mg/L

SDG: 705610
SRR: 69648
Matrix: Water
Associated Prep Batches: NA

Case: 682609
Project: 27927.04.001
LCS Source: Agilent

Analyte	True	Found	Qual	%Rec.	Limit	M	Analysis Date/Time
Total Inorganic Carbon	2.50	2.43		97.2%	90%-110%	Pnx	06/05/2023 10:38
Total Organic Carbon	2.50	2.44		97.6%	90%-110%	Pnx	06/15/2023 09:31
Carbonate	12.5	12.2		97.6%	90%-110%	Pnx	06/05/2023 10:38

Instruments/Methods (M)

Pnx - Phoenix 8000 TOC analyzer/TIC by 9060M
Pnx - Phoenix 8000 TOC analyzer/TOC 9060M
NA - Not Applicable

Form VII-IN

SOUTHWEST RESEARCH INSTITUTE
WetChem Report - Form IX
Detection Limits

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Result Units: mg/L

SDG: 705610
SRR: 69648
Instrument: Phoenix 8000 TOC analyzer

Case: 682609
Project: 27927.04.001

Analyte	Wavelength	RL
Total Inorganic Carbon	NA	0.200
Total Organic Carbon	NA	0.200
Carbonate	NA	1.00

Columns
RL - SwRI Reporting Limit

SOUTHWEST RESEARCH INSTITUTE
WetChem Report - Form XII
Analysis Run Log

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Analytical Batch: 20230623-A001
Analysis Method: TIC by 9060M

SDG: 705610
SRR: 69648
Instrument: Phoenix 8000 TOC analyzer

Case: 682609
Project: 27927.04.001
Start Date: 06/05/2023
End Date: 06/05/2023

Lab Sample ID	Client Sample ID	Time	DF	TIC	TOC
ICV	NA	10:38	1	X	
ICB	NA	10:41	1	X	
Z	Z	10:50	20		
Z	Z	10:57	20		
Z	Z	11:03	20		
Z	Z	11:10	20		
Z	Z	11:17	20		
Z	Z	11:24	20		
Z	Z	11:31	20		
Z	Z	11:38	20		
Z	Z	11:45	20		
Z	Z	11:52	20		
CCV	CCV	12:00	1	X	
CCB	CCB	12:04	1	X	
Z	Z	12:11	20		
Z	Z	12:18	20		
Z	Z	12:24	20		
Z	Z	12:31	20		
Z	Z	12:38	20		
Z	Z	12:45	20		
Z	Z	12:52	20		
Z	Z	12:59	20		
Z	Z	13:06	20		
Z	Z	13:13	20		
CCV2	CCV2	13:18	1	X	
CCB2	CCB2	13:21	1	X	
Z	Z	13:28	20		
Z	Z	13:35	20		
Z	Z	13:41	20		
Z	Z	13:48	20		
Z	Z	13:55	20		
Z	Z	14:01	20		
CCV3	CCV3	14:07	1	X	
CCB3	CCB3	14:11	1	X	
Z	Z	14:20	1		
Z	Z	14:25	1		
Z	Z	14:29	1		
705610 0.1G	TI147-EFF-Comp-A	14:36	10	X	
705610D 0.1G	TI147-EFF-Comp-AD	14:44	10	X	
705610S 0.1G	TI147-EFF-Comp-AMS	14:51	10	X	
705611 0.1G	TI147-Feed-Comp-A	14:59	10	X	
CCV4	CCV4	15:03	1	X	
CCB4	CCB4	15:07	1	X	

SOUTHWEST RESEARCH INSTITUTE
WetChem Report - Form XII
Analysis Run Log

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2
Analytical Batch: 20230623-A002
Analysis Method: TOC 9060M

SDG: 705610
SRR: 69648
Instrument: Phoenix 8000 TOC analyzer

Case: 682609
Project: 27927.04.001
Start Date: 06/15/2023
End Date: 06/15/2023

Lab Sample ID	Client Sample ID	Time	DF	TIC	TOC
ICB	NA	00:09	1		X
ICV	NA	09:31	1		X
Z	Z	09:50	20		
Z	Z	10:04	20		
Z	Z	10:19	20		
Z	Z	10:32	20		
Z	Z	10:46	20		
Z	Z	11:00	20		
Z	Z	11:15	20		
Z	Z	11:29	20		
Z	Z	11:45	20		
Z	Z	11:59	20		
CCV	CCV	12:06	1		X
CCB	CCB	12:13	1		X
Z	Z	12:27	20		
Z	Z	12:42	20		
Z	Z	12:58	20		
Z	Z	13:13	20		
Z	Z	13:28	20		
Z	Z	13:42	20		
Z	Z	13:58	20		
Z	Z	14:12	20		
Z	Z	14:27	20		
Z	Z	14:42	20		
CCV2	CCV2	14:49	1		X
CCB2	CCB2	14:56	1		X
Z	Z	15:09	20		
Z	Z	15:22	20		
Z	Z	15:35	20		
Z	Z	15:49	20		
Z	Z	16:02	20		
Z	Z	16:16	20		
CCV3	CCV3	16:26	1		X
CCB3	CCB3	16:32	1		X
Z	Z	16:46	1		
Z	Z	16:59	1		
Z	Z	17:13	1		
Z	Z	17:29	1		
Z	Z	17:42	1		
Z	Z	17:54	1		
Z	Z	18:08	1		
Z	Z	18:22	1		
Z	Z	18:35	1		
Z	Z	18:49	1		
CCV4	CCV4	18:57	1		X
CCB4	CCB4	19:03	1		X
705610 0.1G	TI147-EFF-Comp-A	19:17	1		X
705611 0.1G	TI147-Feed-Comp-A	19:31	1		X
Z	Z	19:44	1		
Z	Z	19:58	1		
Z	Z	20:11	1		
Z	Z	20:24	1		
705610D 0.1G	TI147-EFF-Comp-AD	20:37	1		X
705610S 0.1G	TI147-EFF-Comp-AMS	20:52	1		X
CCV5	CCV5	20:59	1		X
CCB5	CCB5	21:05	1		X

SOUTHWEST RESEARCH INSTITUTE
WetChem Report - Form XVIII
Preparation/Digestion Summary

Client: Battelle Memorial Institute PNNL
Task Order: 230526-2

SDG: 705610
SRR: 69648

Case: 682609
Project: 27927.04.001

Prep Batch	Method	Preparation Date
20230623-P002	Total Inorganic Carbon	06/05/2023
20230623-P003	TOC 9060 Modified	06/15/2023

Preparation Log

WetChem

A34175

A34175

Southwest Research Institute
San Antonio, Texas 78238

Batch: 20230623-P002 (Ver. 1)
Status: CONSUMED

Client(s): Battelle Memorial Institute PNNL
Task Order(s): 230526-2
SDG(s): 705610
Case(s): 682609
Project(s): 27927.04
Method(s): Total Inorganic Carbon (TAP: 01-0406-159M)
Matrix(s): Aqueous
Balance(s): Bal #135 (AN:020014)
Pipette(s): 5000-9, 1000-5, 200-M
Time In: 06/05/2023 13:07:00

Sample Identification	Client Identification	Initial Weight (g)	Final Volume (mL)
705610	TI147-EFF-Comp-A	0.1125	30
705611	TI147-Feed-Comp-A	0.1129	30

Comments: NA

Procedure:
See TAP 01-0406-002 for details.

CGL - 06/29/2023

Prepared by: MOKEN, JAMES Date: 06/05/2023

Reviewed by: SPIES, RADONNA Date: 06/28/2023

Disposal Int/Date/Loc: RS / 06/28/2023 / NA - Consumed

Preparation Log

WetChem

A34177
A34177

Southwest Research Institute
San Antonio, Texas 78238

Batch: 20230623-P003 (Ver. 1)
Status: CONSUMED

Client(s): Battelle Memorial Institute PNNL
Task Order(s): 230526-2
SDG(s): 705610
Case(s): 682609
Project(s): 27927.04
Method(s): TOC 9060 Modified (TAP: 01-0406-002)
Matrix(s): Aqueous
Balance(s): Bal #135 (AN:020014)
Pipette(s): 5000-9, 1000-5, 200-M
Time In: 06/15/2023 15:30:00

Sample Identification	Client Identification	Initial Weight (g)	Final Volume (mL)
705610	TI147-EFF-Comp-A	0.1127	30
705610D	TI147-EFF-Comp-A	0.1122	30
705610MS ①	TI147-EFF-Comp-A	0.1157	30
705611	TI147-Feed-Comp-A	0.1130	30
Z	NA	0.1019	30
Z	NA	0.1014	30
Z	NA	0.1009	30
Z ①	NA	0.1005	30
Z	NA	0.1103	30
Z	NA	0.1367	30
Z	NA	0.2986	30
Z	NA	0.3038	30
Z	NA	0.1002	30
Z	NA	0.1006	30
Z	NA	0.1000	30
Z	NA	0.1064	30

① spiked 0.075 mL of CI# 220187 Total Organic Carbon 1000 mg/L (Lot# 550222m, Source: ERA, Exp: 02/28/2024)

Comments: NA

Procedure:
See TAP 01-0406-002 for details.

CGL - 06/29/2023

Prepared by: MOKEN, JAMES Date: 06/15/2023

Reviewed by: SPIES, RADONNA Date: 06/29/2023

Disposal Int/Date/Loc: RS / 06/29/2023 / NA - Consumed

Test Report

SwRI Project #:	27927.04.001
SwRI SDG:	705610
SwRI Task Order:	230526-2
SwRI Sample Receipt:	69648
Date Received:	05/18/2023

Purchase Order #: 660825

Prepared by:

Southwest Research Institute®
Department of Analytical and Environmental Chemistry
6220 Culebra Road
San Antonio, Texas 78238

Prepared for:

Battelle Memorial Institute - PNNL
902 Battelle Boulevard
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Attn: Ms. Amy Westesen

Authorized for Release
07/07/2023 12:00PM
Jackie Ranger, Project Manager
jacqueline.ranger@swri.org
210-522-3320

Mike Dammann
Laboratory Director

CASE NARRATIVE

Client: Battelle Memorial Institute PNNL
SDG: 705610
SwRI Project Number: 27927.04.001
SwRI Task Order Number: 230526-2

RADIOLOGICAL ANALYSIS

The sample SDG 705610 consisted of twelve aqueous samples received for radiological analysis. The samples for radiological analysis were reported on an "as received" weight basis. The recommended sample holding time of six months was met.

The sample was analyzed for the following:

Matrix	Analysis	Method
Aqueous	^{239}Neptunium Alpha/Beta analysis	Gas Proportional Counting
Aqueous	^{241}Americium	Alpha Spectroscopy
Aqueous	^{242}Curium, $^{243/244}$Curium	Alpha Spectroscopy
Aqueous	^{238}Plutonium, $^{239/240}$Pu, ^{244}Pu	Alpha Spectroscopy
Aqueous	^{237}Neptunium	Alpha Spectroscopy

Note:

A coverage factor of k=2 was applied to the TPU of all analytes. TPU was calculated using 1 sigma counting error.

The reported MDAs are sample-specific.

Sample Preparation and Digestion

Approximately 0.5 grams of each sample was digested with hydrochloric acid. Approximately 0.1 grams of SwRI sample ID 705611 was digested due to its activity. Once digested, the samples were transferred with a dilute hydrochloric acid to a final volume of 50ml. Aliquots were taken from the digestion for americium, curium, plutonium, and neptunium analyses. The aliquots were evaporated to dryness and nitrated a couple times. The sample aliquots were then transferred with 10 milliliters of a 3M nitric acid / 1M aluminum nitrate solution. Two preparation blanks, a laboratory control sample, and a sample duplicate were also processed with the sample aliquots. Tracers and spikes were added to the sample aliquots prior to evaporation and nitration of the sample aliquots.

Gas Flow Proportional Counting

Daily instrument checks were within control limits and the weekly four hour background was within date and control limits.

^{239}Neptunium tracer

The ^{237}Neptunium samples were counted in the GPC for 30 minutes each for Gross Alpha/Beta analysis prior to counting by alpha spectroscopy. ^{239}Neptunium is used as a tracer for ^{237}Neptunium analysis. ^{243}Americium is added to the samples and ^{239}Neptunium which is in secular equilibrium is separated from the samples. GPC results were corrected to pCi using calibration standards to determine the efficiency.

Client: Battelle Memorial Institute PNNL
SDG: 705610
SwRI Project Number: 27927.04.001
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Alpha Spectroscopy (Am, Cm, Pu, Np)

For all alpha analysis, daily pulser checks were within control limits. The weekly secondary or monthly primary calibration check standards were within date and control limits. The monthly alpha detector background was within date.

The samples were counted for 500 minutes for plutonium and neptunium. The samples were counted for 1000 minutes for americium.

^{241}Americium

^{243}Americium was used as a tracer to follow chemical separation efficiency and losses. Tracer FWHM were within control limits of 100keV. All reported results for the tracers were within the control limits of 30-110% except for SwRI sample ID 705610D. SwRI sample ID 705610D had a tracer recovery of 20.8%. Part of the sample was lost during the precipitation step; however, the tracer recovery met the 5% tracer error requirement and was reported. The result for the preparation blank, SwRI sample ID PB23F21JT4, was less than 3 times the TPU, the MDA, and the RL. The result for the preparation blank, SwRI sample ID PB23F21JT1, was less than 3 times the TPU and RL, but was greater than the MDA. The result for the laboratory control sample was within the control limits of 75-125% recovery. SwRI laboratory sample ID 705610 was analyzed in duplicate and the sample duplicate evaluation ratio was less than three.

^{242}Curium, $^{243/244}$Curium

^{242}Curium and $^{243/244}$Curium were separated, precipitated, and analyzed from the same aliquot as ^{241}Americium. ^{241}Americium was used as the spiking solution in the laboratory control samples and ^{243}Americium was used to determine tracer recovery. ^{243}Americium was used as a tracer to follow chemical separation efficiency and losses. Tracer FWHM were within control limits of 100keV. All reported results for the tracers were within the control limits of 30-110% except for SwRI sample ID 705610D. SwRI sample ID 705610D had a tracer recovery of 20.8%. Part of the sample was lost during the precipitation step; however, the tracer recovery met the 5% tracer error requirement and was reported. The results for both preparation blanks, SwRI sample ID PB23F21JT4 and PB23F21JT1, were less than 3 times the TPU, the MDA, and the RL for both ^{242}Curium and $^{243/244}$Curium. The result for the laboratory control sample was within the control limits of 75-125% recovery. SwRI laboratory sample ID 705610 was analyzed in duplicate and the sample duplicate evaluation ratios were less than three for both isotopes.

Client: Battelle Memorial Institute PNNL
SDG: 705610
SwRI Project Number: 27927.04.001
SwRI Task Order Number: 230526-2

^{238}Plutonium, $^{239/240}$Plutonium

^{242}Plutonium was used as a tracer to follow chemical separation efficiency and losses. All tracer FWHM were within the control limits of 100keV. All reported results for the tracers were within the control limits of 30-110%. The results for both preparation blanks, SwRI sample ID PB23F21JT4 and PB23F21JT1, for ^{238}Pu and $^{239/240}$Pu were less than 3 times the TPU, the MDA, and the RL. The result for the laboratory control sample was within the control limits of 75-125% recovery. SwRI laboratory sample ID 705610 was analyzed in duplicate and the sample duplicate evaluation ratios were less than three for both isotopes.

^{237}Neptunium

^{239}Neptunium was used as a tracer to follow chemical separation efficiency and losses. The ^{239}Np was spiked in using high activity ^{243}Am in secular equilibrium with its ^{239}Np daughter. The neptunium was separated and the decay of the ^{239}Np was calculated from the end of separation. The samples were then precipitated and the filters analyzed by beta GPC to determine the ^{239}Np recovery. The samples were then analyzed by alpha spectroscopy using the tracer recovery from the GPC. All of the results for the tracers were within the control limits of 30-110%. The results for both preparation blanks, SwRI sample ID PB23F21JT2 and PB23F21JT1, were less than 3 times the TPU, the MDA, and the RL. The result for the laboratory control sample was within the control limits of 75-125% recovery. SwRI laboratory sample ID 705610 was analyzed in duplicate and the sample duplicate evaluation ratio was less than three.

Warren A Naegeli

Digitally signed by Warren A Naegeli
Date: 2023.07.06 21:24:02 -05'00'

Prepared by

ALPHA RESULTS

SOUTHWEST RESEARCH INSTITUTE

ALPHA SPECTROMETRY ANALYSIS DATA SHEET

Lab Name: Southwest Research Institute

Client: Battelle Memorial Institute - PNNL

Lab Code: SwRI

Project No.: 27927.04.001

Matrix: Aqueous

Date Received: 05/18/23

SRR #: 69648

PO: 682609

Task Order #: 230526-2

SDG: 705610

AMERICIUM-241, CURIUM-242, 243/244									
Sample ID	Lab System ID	Analyte	Results (pCi/g)	Q	TPU (2s) (pCi/g)	MDA (pCi/g)	Counting Error (2s)	^{243}Am Tracer Rec.	Date Analyzed
Prep Blank	pb23f21jt4	^{241}Am	5.47E-01	U	3.95E-01	6.11E-01	3.85E-01	85.0%	06/30/23
	pb23f21jt4	^{242}Cm	0.00E+00	U	1.45E-01	3.91E-01	1.45E-01	85.0%	06/30/23
	pb23f21jt4	$^{243/244}$Cm	4.91E-02	U	1.39E-01	3.76E-01	1.39E-01	85.0%	06/30/23
Lab Control	lcs23f21jt1	^{241}Am	4.85E+01		8.27E+00	9.15E-01	3.07E+00	93.2%	06/30/23
	lcs23f21jt1	^{242}Cm	9.85E-02	U	1.71E-01	3.77E-01	1.71E-01	93.2%	06/30/23
	lcs23f21jt1	$^{243/244}$Cm	4.74E-02	U	1.34E-01	3.62E-01	1.34E-01	93.2%	06/30/23
True Value	-----	^{241}Am	4.88E+01		-----	-----	-----	-----	-----
	-----	^{242}Cm	-----		-----	-----	-----	-----	-----
	-----	$^{243/244}$Cm	-----		-----	-----	-----	-----	-----
Recovery	-----	^{241}Am	99.4%		-----	-----	-----	-----	-----
	-----	^{242}Cm	-----		-----	-----	-----	-----	-----
	-----	$^{243/244}$Cm	-----		-----	-----	-----	-----	-----
Prep Blank	pb23f21jt1	^{241}Am	5.88E-01		3.65E-01	3.75E-01	3.53E-01	85.1%	06/30/23
	pb23f21jt1	^{242}Cm	0.00E+00	U	1.43E-01	3.85E-01	1.43E-01	85.1%	06/30/23
	pb23f21jt1	$^{243/244}$Cm	0.00E+00	U	1.37E-01	3.71E-01	1.37E-01	85.1%	06/30/23
TI147-EFF-Comp-A	705610	^{241}Am	2.05E+00		6.79E-01	3.26E-01	5.97E-01	89.0%	06/30/23
	705610	^{242}Cm	0.00E+00	U	1.48E-01	3.99E-01	1.48E-01	89.0%	06/30/23
	705610	$^{243/244}$Cm	1.69E-01	U	1.91E-01	3.24E-01	1.89E-01	89.0%	06/30/23
Duplicate result	705610D	^{241}Am	2.72E+00		1.53E+00	1.39E+00	1.45E+00	20.8%	06/30/23
	705610D	^{242}Cm	0.00E+00	U	6.29E-01	1.70E+00	6.29E-01	20.8%	06/30/23
	705610D	$^{243/244}$Cm	0.00E+00	U	5.10E-01	1.38E+00	5.10E-01	20.8%	06/30/23
Dup Evaluation	-----	^{241}Am	0.8		-----	-----	-----	-----	-----
	-----	^{242}Cm	0.0		-----	-----	-----	-----	-----
	-----	$^{243/244}$Cm	0.6		-----	-----	-----	-----	-----
TI147-Feed-Comp-A	705611	^{241}Am	1.16E+02		2.07E+01	1.97E+00	9.77E+00	91.6%	06/30/23
	705611	^{242}Cm	1.01E+00		1.14E+00	1.93E+00	1.13E+00	91.6%	06/30/23
	705611	$^{243/244}$Cm	1.64E+01		4.50E+00	1.56E+00	3.68E+00	91.6%	06/30/23
TI147-L-16-A	705612	^{241}Am	2.43E+00		7.60E-01	4.09E-01	6.56E-01	86.9%	06/30/23
	705612	^{242}Cm	0.00E+00	U	2.09E-01	6.42E-01	2.09E-01	86.9%	06/30/23
	705612	$^{243/244}$Cm	4.66E-01	U	3.77E-01	6.84E-01	3.69E-01	86.9%	06/30/23

Q - Data Qualifier. MDA - Minimum Detectable Activity. TPU - Total Propagated Uncertainty. U - Less than MDA. MDAs are sample specific.

SOUTHWEST RESEARCH INSTITUTE

ALPHA SPECTROMETRY ANALYSIS DATA SHEET

Lab Name: Southwest Research Institute

Client: Battelle Memorial Institute - PNNL

Lab Code: SwRI

Project No.: 27927.04.001

Matrix: Aqueous

Date Received: 05/18/23

SRR #: 69648

PO: 682609

Task Order #: 230526-2

SDG: 705610

AMERICIUM-241, CURIUM-242, 243/244									
Sample ID	Lab System ID	Analyte	Results (pCi/g)	Q	TPU (2s) (pCi/g)	MDA (pCi/g)	Counting Error (2s)	^{243}Am Tracer Rec.	Date Analyzed
TI147-L-18-A	705613	^{241}Am	2.06E+00		6.67E-01	3.09E-01	5.82E-01	91.1%	06/30/23
	705613	^{242}Cm	9.87E-02	U	1.72E-01	3.78E-01	1.71E-01	91.1%	06/30/23
	705613	$^{243/244}$Cm	2.80E-01	U	2.31E-01	3.06E-01	2.27E-01	91.1%	06/30/23
TI147-L-20-A	705614	^{241}Am	2.03E+00		7.01E-01	5.42E-01	6.24E-01	84.0%	06/30/23
	705614	^{242}Cm	0.00E+00	U	2.16E-01	6.64E-01	2.16E-01	84.0%	06/30/23
	705614	$^{243/244}$Cm	1.75E-01	U	2.49E-01	5.38E-01	2.48E-01	84.0%	06/30/23
TI147-L-22-A	705615	^{241}Am	2.27E+00		7.34E-01	5.17E-01	6.40E-01	90.3%	06/30/23
	705615	^{242}Cm	1.03E-01	U	1.79E-01	3.94E-01	1.78E-01	90.3%	06/30/23
	705615	$^{243/244}$Cm	3.34E-01	U	2.69E-01	4.00E-01	2.64E-01	90.3%	06/30/23
TI147-L-24-A	705616	^{241}Am	2.00E+00		6.76E-01	3.33E-01	5.97E-01	87.1%	06/30/23
	705616	^{242}Cm	5.33E-02	U	1.51E-01	4.07E-01	1.51E-01	87.1%	06/30/23
	705616	$^{243/244}$Cm	1.73E-01	U	1.95E-01	3.30E-01	1.93E-01	87.1%	06/30/23
TI147-L-26-A	705617	^{241}Am	1.99E+00		6.81E-01	5.20E-01	6.04E-01	90.9%	06/30/23
	705617	^{242}Cm	-5.18E-02	U	1.47E-01	4.96E-01	1.46E-01	90.9%	06/30/23
	705617	$^{243/244}$Cm	2.94E-01	U	2.82E-01	5.16E-01	2.78E-01	90.9%	06/30/23
TI147-P-14-A	705618	^{241}Am	2.04E+00		6.93E-01	4.24E-01	6.14E-01	85.6%	06/30/23
	705618	^{242}Cm	0.00E+00	U	1.53E-01	4.14E-01	1.53E-01	85.6%	06/30/23
	705618	$^{243/244}$Cm	-8.79E-02	U	1.53E-01	5.41E-01	1.52E-01	85.6%	06/30/23
TI147-P-16-A	705619	^{241}Am	1.21E+00		5.18E-01	5.15E-01	4.81E-01	90.8%	06/30/23
	705619	^{242}Cm	0.00E+00	U	1.45E-01	3.92E-01	1.45E-01	90.8%	06/30/23
	705619	$^{243/244}$Cm	8.31E-02	U	2.04E-01	5.11E-01	2.04E-01	90.8%	06/30/23
TI147-P-18-A	705620	^{241}Am	1.62E+00		5.91E-01	3.98E-01	5.33E-01	91.9%	06/30/23
	705620	^{242}Cm	5.09E-02	U	1.44E-01	3.89E-01	1.44E-01	91.9%	06/30/23
	705620	$^{243/244}$Cm	2.89E-01	U	2.52E-01	3.95E-01	2.48E-01	91.9%	06/30/23
TI147-P-20-A	705621	^{241}Am	3.36E+00		9.05E-01	3.02E-01	7.33E-01	93.9%	07/02/23
	705621	^{242}Cm	9.76E-02	U	1.70E-01	3.73E-01	1.69E-01	93.9%	07/02/23
	705621	$^{243/244}$Cm	1.69E+00		5.85E-01	3.00E-01	5.21E-01	93.9%	07/02/23

Q - Data Qualifier. MDA - Minimum Detectable Activity. TPU - Total Propagated Uncertainty. U - Less than MDA. MDAs are sample specific.

SOUTHWEST RESEARCH INSTITUTE

ALPHA SPECTROMETRY ANALYSIS DATA SHEET

Lab Name: Southwest Research Institute

Client: Battelle Memorial Institute - PNNL

Lab Code: SwRI

Project No.: 27927.04.001

Matrix: Aqueous

Date Received: 05/18/23

SRR #: 69648

PO: 682609

Task Order #: 230526-2

SDG: 705610

NEPTUNIUM-237

Sample ID	Lab System ID	Analyte	Results (pCi/g)	Q	TPU (2s) (pCi/g)	MDA (pCi/g)	Counting Error (2s)	^{239}Np Tracer Rec.	Date Analyzed
Prep Blank	pb23f21jt2	^{237}Np	5.33E-02	U	2.39E-01	7.50E-01	2.39E-01	82.3%	06/28/23
Lab Control	lcs23f21jt2	^{237}Np	6.06E+01		8.78E+00	7.67E-01	5.15E+00	80.4%	06/28/23
True Value	-----	^{237}Np	5.47E+01		-----	-----	-----	-----	-----
Recovery	-----	^{237}Np	110.7%		-----	-----	-----	-----	-----
Prep Blank	pb23f21jt1	^{237}Np	-1.09E-01	U	2.68E-01	9.49E-01	2.67E-01	79.8%	06/28/23
TI147-EFF-Comp-A	705610	^{237}Np	1.27E-01	U	3.88E-01	1.02E+00	3.88E-01	91.3%	06/28/23
Duplicate result	705610D	^{237}Np	1.31E-01	U	2.63E-01	6.14E-01	2.62E-01	87.1%	06/28/23
Dup Evaluation	-----	^{237}Np	0.0		-----	-----	-----	-----	-----
TI147-Feed-Comp-A	705611	^{237}Np	1.95E+00	U	2.26E+00	4.32E+00	2.25E+00	89.3%	06/28/23
TI147-L-16-A	705612	^{237}Np	8.66E-01		6.17E-01	7.36E-01	6.08E-01	81.1%	06/28/23
TI147-L-18-A	705613	^{237}Np	6.79E-01	U	5.71E-01	9.03E-01	5.65E-01	85.8%	06/28/23
TI147-L-20-A	705614	^{237}Np	7.95E-01		5.77E-01	6.57E-01	5.69E-01	84.8%	06/28/23
TI147-L-22-A	705615	^{237}Np	1.45E+00		7.48E-01	6.16E-01	7.28E-01	89.0%	06/28/23
TI147-L-24-A	705616	^{237}Np	4.66E-01	U	4.60E-01	7.13E-01	4.57E-01	84.6%	06/28/23
TI147-L-26-A	705617	^{237}Np	2.86E-01	U	3.83E-01	7.29E-01	3.81E-01	82.4%	06/28/23
TI147-P-14-A	705618	^{237}Np	5.78E-01	U	5.32E-01	8.37E-01	5.27E-01	80.9%	06/29/23
TI147-P-16-A	705619	^{237}Np	9.88E-01		6.42E-01	6.61E-01	6.31E-01	87.3%	06/29/23
TI147-P-18-A	705620	^{237}Np	7.25E-01		5.50E-01	6.93E-01	5.44E-01	84.9%	06/29/23
TI147-P-20-A	705621	^{237}Np	7.95E-01		5.76E-01	6.57E-01	5.69E-01	84.1%	06/29/23

Q - Data Qualifier. MDA - Minimum Detectable Activity. TPU - Total Propagated Uncertainty. U - Less than MDA. MDAs are sample specific.

SOUTHWEST RESEARCH INSTITUTE

ALPHA SPECTROMETRY ANALYSIS DATA SHEET

Lab Name: Southwest Research Institute

Client: Battelle Memorial Institute - PNNL

Lab Code: SwRI

Project No.: 27927.04.001

Matrix: Aqueous

Date Received: 05/18/23

SRR #: 69648

PO: 682609

Task Order #: 230526-2

SDG: 705610

PLUTONIUM-238, 239/240, 244

Sample ID	Lab System ID	Analyte	Results (pCi/g)	Q	TPU (2s) (pCi/g)	MDA (pCi/g)	Counting Error (2s)	^{242}Pu Tracer Rec.	Date Analyzed
Prep Blank	pb23f21jt4	^{238}Pu	0.00E+00	U	3.27E-01	8.83E-01	3.27E-01	71.4%	06/28/23
	pb23f21jt4	$^{239/240}$Pu	1.73E-01	U	3.47E-01	8.11E-01	3.46E-01	71.4%	06/28/23
	pb23f21jt4	^{244}Pu	1.15E-01	U	3.27E-01	8.83E-01	3.26E-01	71.4%	06/28/23
Lab Control	lcs23f21jt1	^{238}Pu	7.37E-01	U	6.04E-01	8.06E-01	5.96E-01	79.7%	06/28/23
	lcs23f21jt1	$^{239/240}$Pu	5.00E+01		8.25E+00	8.07E-01	4.60E+00	79.7%	06/28/23
	lcs23f21jt1	^{244}Pu	3.16E-01	U	4.24E-01	8.06E-01	4.21E-01	79.7%	06/28/23
True Value	-----	^{238}Pu	-----		-----	-----	-----	-----	-----
	-----	$^{239/240}$Pu	5.00E+01		-----	-----	-----	-----	-----
	-----	^{244}Pu	-----		-----	-----	-----	-----	-----
Recovery	-----	^{238}Pu	-----		-----	-----	-----	-----	-----
	-----	$^{239/240}$Pu	100.0%		-----	-----	-----	-----	-----
	-----	^{244}Pu	-----		-----	-----	-----	-----	-----
Prep Blank	pb23f21jt1	^{238}Pu	0.00E+00	U	3.27E-01	8.85E-01	3.27E-01	72.5%	06/28/23
	pb23f21jt1	$^{239/240}$Pu	1.16E-01	U	3.28E-01	8.85E-01	3.27E-01	72.5%	06/28/23
	pb23f21jt1	^{244}Pu	1.16E-01	U	3.27E-01	8.84E-01	3.27E-01	72.5%	06/28/23
TI147-EFF-Comp-A	705610	^{238}Pu	3.75E+00		1.34E+00	7.03E-01	1.24E+00	74.3%	06/28/23
	705610	$^{239/240}$Pu	2.22E+01		4.28E+00	7.03E-01	2.98E+00	74.3%	06/28/23
	705610	^{244}Pu	2.00E-01	U	3.47E-01	7.65E-01	3.46E-01	74.3%	06/28/23
Duplicate result	705610D	^{238}Pu	2.90E+00		1.17E+00	7.15E-01	1.10E+00	72.4%	06/28/23
	705610D	$^{239/240}$Pu	2.28E+01		4.40E+00	7.15E-01	3.05E+00	72.4%	06/28/23
	705610D	^{244}Pu	5.59E-01	U	5.14E-01	7.14E-01	5.08E-01	72.4%	06/28/23
Dup Evaluation	-----	^{238}Pu	1.0		-----	-----	-----	-----	-----
	-----	$^{239/240}$Pu	0.2		-----	-----	-----	-----	-----
	-----	^{244}Pu	1.2		-----	-----	-----	-----	-----
TI147-Feed-Comp-A	705611	^{238}Pu	2.18E+01		7.29E+00	3.79E+00	6.64E+00	74.0%	06/28/23
	705611	$^{239/240}$Pu	1.24E+02		2.33E+01	3.79E+00	1.57E+01	74.0%	06/28/23
	705611	^{244}Pu	1.98E+00	U	2.23E+00	3.78E+00	2.21E+00	74.0%	06/28/23
TI147-L-16-A	705612	^{238}Pu	3.99E+00		1.34E+00	7.88E-01	1.22E+00	80.6%	06/28/23
	705612	$^{239/240}$Pu	2.86E+01		5.06E+00	6.37E-01	3.22E+00	80.6%	06/28/23
	705612	^{244}Pu	9.05E-02	U	2.56E-01	6.92E-01	2.56E-01	80.6%	06/28/23

Q - Data Qualifier. MDA - Minimum Detectable Activity. TPU - Total Propagated Uncertainty. U - Less than MDA. MDAs are sample specific.

SOUTHWEST RESEARCH INSTITUTE

ALPHA SPECTROMETRY ANALYSIS DATA SHEET

Lab Name: Southwest Research Institute

Client: Battelle Memorial Institute - PNNL

Lab Code: SwRI

Project No.: 27927.04.001

Matrix: Aqueous

Date Received: 05/18/23

SRR #: 69648

PO: 682609

Task Order #: 230526-2

SDG: 705610

PLUTONIUM-238, 239/240, 244

Sample ID	Lab System ID	Analyte	Results (pCi/g)	Q	TPU (2s) (pCi/g)	MDA (pCi/g)	Counting Error (2s)	^{242}Pu Tracer Rec.	Date Analyzed
TI147-L-18-A	705613	^{238}Pu	4.41E+00		1.45E+00	8.33E-01	1.32E+00	78.1%	06/28/23
	705613	$^{239/240}$Pu	2.89E+01		5.20E+00	8.33E-01	3.34E+00	78.1%	06/28/23
	705613	^{244}Pu	1.44E-01	U	2.88E-01	6.73E-01	2.87E-01	78.1%	06/28/23
TI147-L-20-A	705614	^{238}Pu	6.19E+00		1.82E+00	7.77E-01	1.60E+00	73.2%	06/28/23
	705614	$^{239/240}$Pu	3.52E+01		6.19E+00	7.77E-01	3.79E+00	73.2%	06/28/23
	705614	^{244}Pu	5.07E-01	U	5.02E-01	7.76E-01	4.97E-01	73.2%	06/28/23
TI147-L-22-A	705615	^{238}Pu	5.94E+00		1.72E+00	8.19E-01	1.51E+00	80.8%	06/28/23
	705615	$^{239/240}$Pu	3.34E+01		5.79E+00	7.21E-01	3.55E+00	80.8%	06/28/23
	705615	^{244}Pu	1.88E-01	U	3.27E-01	7.20E-01	3.26E-01	80.8%	06/28/23
TI147-L-24-A	705616	^{238}Pu	3.99E+00		1.38E+00	6.92E-01	1.26E+00	76.3%	06/28/23
	705616	$^{239/240}$Pu	3.50E+01		6.09E+00	6.91E-01	3.71E+00	76.3%	06/28/23
	705616	^{244}Pu	6.88E-01	U	5.64E-01	7.52E-01	5.56E-01	76.3%	06/28/23
TI147-L-26-A	705617	^{238}Pu	6.10E+00		1.88E+00	9.64E-01	1.67E+00	67.5%	06/28/23
	705617	$^{239/240}$Pu	3.81E+01		6.76E+00	7.79E-01	4.11E+00	67.5%	06/28/23
	705617	^{244}Pu	2.22E-01	U	3.85E-01	8.47E-01	3.84E-01	67.5%	06/28/23
TI147-P-14-A	705618	^{238}Pu	3.37E+00		1.24E+00	8.15E-01	1.15E+00	80.6%	06/28/23
	705618	$^{239/240}$Pu	2.17E+01		4.12E+00	6.58E-01	2.86E+00	80.6%	06/28/23
	705618	^{244}Pu	6.55E-01	U	5.37E-01	7.16E-01	5.30E-01	80.6%	06/28/23
TI147-P-16-A	705619	^{238}Pu	3.84E+00		1.38E+00	8.78E-01	1.27E+00	73.7%	06/28/23
	705619	$^{239/240}$Pu	2.32E+01		4.45E+00	8.78E-01	3.07E+00	73.7%	06/28/23
	705619	^{244}Pu	8.07E-01		6.16E-01	7.72E-01	6.05E-01	73.7%	06/28/23
TI147-P-18-A	705620	^{238}Pu	3.12E+00		1.27E+00	1.15E+00	1.19E+00	75.8%	06/28/23
	705620	$^{239/240}$Pu	2.17E+01		4.26E+00	7.30E-01	3.01E+00	75.8%	06/28/23
	705620	^{244}Pu	0.00E+00	U	2.94E-01	7.94E-01	2.94E-01	75.8%	06/28/23
TI147-P-20-A	705621	^{238}Pu	5.00E+00		1.56E+00	7.36E-01	1.40E+00	76.8%	06/28/23
	705621	$^{239/240}$Pu	2.58E+01		4.75E+00	6.76E-01	3.16E+00	76.8%	06/28/23
	705621	^{244}Pu	2.88E-01	U	3.86E-01	7.35E-01	3.84E-01	76.8%	06/28/23

Q - Data Qualifier. MDA - Minimum Detectable Activity. TPU - Total Propagated Uncertainty. U - Less than MDA. MDAs are sample specific.

Appendix C – Batch Contact Results

Table C.1 provides the experimental results used to produce the SY-101 Cs distribution coefficient (K_d) curves and isotherms at four contact temperatures (Figure 4.1 and Figure 4.2 in the main body of this report). The dry crystalline silicotitanate (CST) masses were based on F-factors of 0.918 and 0.881 for 7 M Na AP-105 and 5.5 M Na AP-105, respectively at the nominal 105 °C drying temperature.

Table C.1.SY-101 Tank Waste Isotherm Data

Sample ID	Dry CST Mass (g)	SY-101 Vol. (mL)	Initial Cs Conc. (M)	Equil. Cs Conc. (M)	K_d (mL/g)	Q (mmoles Cs/g)
13.4 °C						
TI148-S1-13	0.0745	14.9311	3.31E-5	1.03E-06	6215	6.43E-03
TI148-S1-13-d	0.0748	14.9479	3.31E-5	1.01E-06	6333	6.41E-03
TI148-S2-13	0.0740	14.9290	7.52E-5	2.33E-06	6320	1.47E-02
TI148-S2-13-d	0.0739	14.9087	7.52E-5	2.36E-06	6237	1.47E-02
TI148-S3-13	0.0754	14.9121	1.24E-4	4.06E-06	5868	2.38E-02
TI148-S3-13-d	0.0742	14.9509	1.24E-4	4.12E-06	5851	2.42E-02
TI148-S4-13	0.0735	14.9568	3.39E-4	1.11E-05	5972	6.67E-02
TI148-S4-13-d	0.0752	14.9598	3.39E-4	1.06E-05	6218	6.53E-02
TI148-S5-13	0.0742	14.9041	8.10E-4	2.46E-05	6386	1.58E-01
TI148-S5-13-d	0.0746	14.9186	8.10E-4	2.65E-05	5886	1.57E-01
TI148-S6-13	0.0750	14.9389	1.47E-2	1.23E-02	39	4.77E-01
TI148-S6-13-d	0.0752	14.9352	1.47E-2	1.24E-02	38	4.71E-01
15.6 °C						
TI148-S1-16	0.0771	14.9783	3.31E-5	1.21E-06	5185	6.20E-03
TI148-S1-16-d	0.0763	14.9538	3.31E-5	1.16E-06	5415	6.26E-03
TI148-S2-16	0.0757	14.9640	7.52E-5	2.76E-06	5210	1.43E-02
TI148-S2-16-d	0.0760	14.8939	7.52E-5	2.67E-06	5314	1.42E-02
TI148-S3-16	0.0763	15.0176	1.24E-4	4.95E-06	4743	2.35E-02
TI148-S3-16-d	0.0764	14.9312	1.24E-4	4.68E-06	4976	2.34E-02
TI148-S4-16	0.0775	15.0043	3.39E-4	1.26E-05	5011	6.32E-02
TI148-S4-16-d	0.0770	14.8884	3.39E-4	1.23E-05	5109	6.32E-02
TI148-S5-16	0.0772	14.9976	8.10E-4	2.83E-05	5377	1.52E-01
TI148-S5-16-d	0.0752	14.9296	8.10E-4	2.94E-05	5279	1.55E-01
TI148-S6-16	0.0758	15.0159	1.47E-2	1.28E-02	29	3.80E-01
TI148-S6-16-d	0.0743	14.9712	1.47E-2	1.28E-02	30	3.81E-01
20.3 °C						
TI148-S1-21	0.0748	14.9598	3.31E-5	1.47E-06	4306	6.33E-03
TI148-S1-21-d	0.0753	14.9458	3.31E-5	1.45E-06	4328	6.28E-03
TI148-S2-21	0.0755	14.9910	7.52E-5	3.53E-06	4020	1.42E-02
TI148-S2-21-d	0.0738	14.9511	7.52E-5	3.57E-06	4018	1.45E-02
TI148-S3-21	0.0747	14.9713	1.24E-4	5.93E-06	4007	2.37E-02
TI148-S3-21-d	0.0741	14.9289	1.24E-4	6.05E-06	3951	2.38E-02
TI148-S4-21	0.0746	14.9630	3.39E-4	1.51E-05	4292	6.49E-02
TI148-S4-21-d	0.0756	14.9459	3.39E-4	1.48E-05	4347	6.41E-02
TI148-S5-21	0.0747	14.9634	8.10E-4	3.63E-05	4244	1.55E-01
TI148-S5-21-d	0.0754	14.9444	8.10E-4	3.63E-05	4225	1.53E-01
TI148-S6-21	0.0758	14.9297	1.47E-2	1.22E-02	41	4.98E-01
TI148-S6-21-d	0.0750	14.9225	1.47E-2	1.09E-02	71	7.73E-01

34.8 °C						
TI148-S1-35	0.0748	15.0703	3.31E-5	2.96E-06	2051	6.07E-03
TI148-S1-35-d	0.0766	14.9863	3.31E-5	2.83E-06	2082	5.92E-03
TI148-S2-35	0.0754	14.9881	7.52E-5	6.49E-06	2100	1.37E-02
TI148-S2-35-d	0.0756	14.9641	7.52E-5	6.85E-06	1962	1.35E-02
TI148-S3-35	0.0760	14.9751	1.24E-4	1.14E-05	1939	2.22E-02
TI148-S3-35-d	0.0751	14.9473	1.24E-4	1.09E-05	2057	2.26E-02
TI148-S4-35	0.0745	14.8944	3.39E-4	4.07E-05	1457	5.96E-02
TI148-S5-35	0.0751	14.9963	8.10E-4	5.53E-05	2729	1.51E-01
TI148-S6-35	0.0766	15.0399	1.47E-2	1.14E-02	58	6.57E-01
TI148-S6-35-d	0.0769	15.0096	1.47E-2	1.13E-02	59	6.69E-01

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