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Summary of Results from Batch 1 Qualification Samples for Tank Closure Cesium Removal 1A (TCCR 1A)

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EXECUTIVE SUMMARY

Savannah River Remediation (SRR)[a] is currently operating the Tank Closure Cesium Removal 1A (TCCR 1A) process to remove ^{137}Cs from tank waste supernate using an ion exchange process. As part of that process, Savannah River National Laboratory (SRNL) receives and analyzes samples in support of the qualification of each waste supernate batch to be processed. SRNL recently received supernate samples retrieved from Tank 10H as well as in-tank batch contact samples for characterization in support of qualifying Batch 1 for processing through the TCCR 1A unit.

SRNL received and characterized several sets of samples collected from Tank 10H in support of Batch 1 qualification for TCCR 1A. This included two sets of interim supernate samples collected in November 2021 during recirculation of the tank, as well as the qualification dip supernate samples received in early December. Density measurements were performed on the two sets of November samples and a full suite of characterization was performed on the December qualification samples. In addition, a set of four in-tank batch contact samples of ion exchange media were received and characterized after a 10-day soak period in Tank 10H.

Density measurements of the two sets of interim samples received in late November 2021 indicated some stratification within the tank, although the difference between the highest and lowest density in the set decreased for the second set of samples indicating increased homogeneity in the tank with continued recirculation. The three dip samples received in early December for batch qualification were not combined but analyzed individually. One sample (HTF-10-21-127) did contain some visible solids and therefore, the analyses were performed on a sample of the filtrate as well as some analyses on a sample of the digested slurry. The average sodium concentration of the three samples was 6.44 M but ranged from 5.46 M in HTF-10-21-126 to 7.00 M in HTF-10-21-127. The total Cs in the dip samples ranged from 5.94 mg/L to 8.68 mg/L, and the ^{137}Cs activity ranged from 1.85E+08 dpm/mL to 2.65E+08 dpm/mL.

A set of four in-tank batch contact samples (two pairs), consisting of 0.1 g of crystalline silicotitanate (CST, IONSIV™ R9120-B, 30x60) contained within a teabag device, were also received at SRNL in December 2021 after being suspended in Tank 10H for a period of 10 days at depths of 75”, 79”, 91”, and 99” from the bottom of the tank. At SRNL the CST was rinsed to remove excess salt solution and the CST was then air dried before being digested for analysis. Results of the analysis indicated a ^{137}Cs loading of 6.22E+10 ± 2.08E+09 dpm/g or 28.0 ± 0.939 Ci/kg_{CST} for the upper pair of teabags (B3/B4) and 8.08E+10 ± 8.62E+09 dpm/g or 36.4 ± 3.88 Ci/kg_{CST} for the lower pair of teabags (B5/B6). These values represent bounding upper limits as they include the addition of two sigma uncertainty from replicate analysis of the individual teabag samples as well as the addition of the small amount of ^{137}Cs activity measured in the rinse solutions. The above values are based on the air-dried mass of CST. Correcting to the true dry mass using a F-factor of 0.8107 results in maximum loadings of 34.5 ± 1.16 Ci/kg_{CST} and 44.9 ± 4.79 Ci/kg_{CST} for teabags B3/B4 and B5/B6, respectively. ZAM modeling was performed using the measured compositions of the three qualification samples. The modeling predicted a maximum Cs loading approximately 1.4x higher than the measured result when based upon the composition of HTF-10-21-125 or HTF-10-21-127 or ~2x higher when based upon the composition of HTF-10-21-126 which had a lower Na^+ concentration. In general, these ratios (expected/measured) are lower compared to what was observed for the prior TCCR in-tank batch contact testing performed for Batches 1A – 3 where the ZAM results were always >2x higher than the measured values.

[a] The liquid waste contractor changed on 2/27/22 becoming Savannah River Mission Completion (SRMC).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CST	crystalline silicotitanate
DI	deionized
ELN	Electronic Laboratory Notebook
IC	ion chromatography
ICP-ES	inductively coupled plasma – emission spectroscopy
ICP-MS	inductively coupled plasma – mass spectrometry
LSC	liquid scintillation counting
M&TE	Measurement and Test Equipment
PMP	polymethylpentene
SaM	Sensing and Metrology
SRNL	Savannah River National Laboratory
SRR	Savannah River Remediation
TCCR 1A	Tank Closure Cesium Removal 1A
TIC/TOC	total inorganic carbon/total organic carbon
TTQAP	Task Technical and Quality Assurance Plan
TTR	Technical Task Request
VDS	variable depth sample
ZAM	ZAM (Zheng, Anthony, and Miller) Isotherm Model

1.0 Introduction

In support of the Tank Closure Cesium Removal 1A (TCCR 1A) program, SRNL analyzed several samples from Tank 10H, including supernate samples and the in-tank crystalline silicotitanate (CST, IONSIV™ R9120-B, 30x60) batch contact equilibrium (or "teabag") samples deployed in that tank. Tank 10H serves as the feed tank for the TCCR 1A system, receiving dissolved salt solution from Tank 9H. Salt was dissolved in Tank 9H in two batches and these supernate batches were transferred to Tank 10H in May and June of 2021. A total of 28,726 gallons comprising Batch 1A were transferred on May 2-3, 2021 and 67,479 gallons comprising Batch 1B were transferred on June 23-25, 2021. SRNL previously received and characterized samples from each of the two Tank 9H dissolved salt batches (Batch 1A and 1B).[1]

On August 11, 2021, 21,680 gallons of domestic water were added to Tank 10H. Recirculation of the tank was planned to immediately follow; however, failure of the pump in Tank 10H caused a delay due to the need for replacement. The pump was replaced in October 2021, and two additions of NaOH reagent were also made in October – 3,461 gallons on October 19, 2021 and 3,508 gallons on October 25, 2021. Recirculation of the tank began on October 27, 2021 and continued until October 31, 2021. On November 1, 2021 a set of batch qualification samples were collected (surface and variable depth) and sent to SRNL for characterization, and the in-tank batch contact test vials were deployed into the tank for a 10-day contact. Following the 10-day contact, the vials were retrieved and sent to SRNL for analysis. Results from analysis of the November 2021 batch qualification and in-tank batch contact samples were documented in a previous report.[2] Analysis of the surface and variable depth samples (VDS) collected in November indicated stratification within the tank. Therefore, an additional 10,027 gallons of domestic water were added to Tank 10H on November 18, 2021 followed by a period of recirculation. During the recirculation period two sets of samples (one surface and two VDS in each set) were collected. The first set of samples were collected on November 23, 2021 and the second set were collected on November 28, 2021 and were sent to SRNL for density measurements. Finally, recirculation was stopped and a final set of qualification samples were collected from Tank 10H on December 2, 2021 (a surface and two VDS). The same day four in-tank batch contact test vials were deployed into the tank for a 10-day contact. Following the 10-day contact, the vials were retrieved and sent to SRNL for characterization. Expedited results from analysis of the December qualification samples were previously documented in a memo.[3] Those results are also included here for completeness, along with the results from the remaining analyses.

2.0 Experimental Procedure

2.1 Tank 10H Interim Samples (HTF-10-21-118 through HTF-10-21-123)

Three 200-mL dip samples were received from Tank 10H on November 23, 2021, one surface and two VDS. Sample HTF-10-21-118 was collected from the surface, HTF-10-21-119 was collected from a depth of 75" from the tank bottom, and HTF-10-21-120 was collected at a depth of 84" from the tank bottom.[4] An additional three 200-mL dip samples were collected from Tank 10H on November 28, 2021 and delivered to SRNL for density measurement. Sample HTF-10-21-121 was collected from the surface, HTF-10-21-122 was collected from a depth of 84" from the tank bottom, and HTF-10-21-123 was collected from a depth of 70" from the tank bottom.[4] Once placed inside the Shielded Cells, the samples were opened and transferred to polymethylpentene (PMP) beakers for observation after shaking by hand (manipulator) to mix. Photographs of the samples are provided in Figure 3-1. The densities of the samples were measured in duplicate, using a measurement and test equipment (M&TE) calibrated balance and 2-mL density tubes at ambient temperature. Samples used for density measurements were returned to the sample bottles.

2.2 Tank 10H Batch Qualification Samples (HTF-10-21-125, HTF-10-21-126, and HTF-10-21-127)

Three 200-mL dip samples were retrieved from Tank 10H on December 2, 2021 and delivered to SRNL. One sample was collected from the surface (HTF-10-21-125), one from a depth of 98" from the tank bottom

(HTF-10-21-126), and one from a depth of 70" from the tank bottom (HTF-10-21-127).[5] Once placed inside the Shielded Cells, the samples were opened and transferred to glass beakers for observation after shaking by hand (manipulator) to mix. Photographs of the samples are provided in Figure 3-2. The samples were not combined and were analyzed individually. A portion of sample HTF-10-21-127 was filtered through a 0.2-µm cellulose nitrate filter to give a filtrate sample that was used for the full suite of analyses. In addition, an aliquot of the as-received HTF-10-21-127 slurry was digested and analyzed. The densities of the samples were measured using an M&TE balance and 2-mL density tubes at ambient temperature. Samples used for density measurements were returned to the sample bottles. Following the density measurements, aliquots of the samples (as-received for -125 and -126, filtrate for -127) were diluted with either deionized (DI) water or 3 M nitric acid and were submitted to Sensing and Metrology (SaM) for a suite of analyzes as described in the Task Technical and Quality Assurance Plan (TTQAP).[6]

2.3 Tank 10H In-Tank Batch Contact Samples (HTF-10-21-128, HTF-10-21-129, HTF-10-21-130, and HTF-10-21-131)

Four modified sample vials containing the CST teabags[7] which had been suspended in Tank 10H supernate at depths of 75", 79", 91", and 99" from the tank bottom, for a total of ~10 days were received at SRNL on December 13, 2021 (removed from the tank on 12/12/21). The teabags were removed from the sample vials in the Shielded Cells and were processed according to the established procedure.[8] Duplicate aliquots of the CST standard were processed alongside the teabag samples and were submitted for identical analyses. The CST standard is from the same batch of pre-treated CST that was used in the teabags.[9] After completion of rinsing followed by air drying (~39 hours), the CST was weighed and subjected to hot HF-HNO_3 digestion. Aliquots of the digestion solutions from the teabag samples and the standard samples were then submitted to SaM for a suite of analyses as described in the TTQAP.[6] In addition to the digested CST results, samples of the soak solutions generated during processing of the teabags were also submitted for analysis and the results from those samples are also reported here.

2.4 Modeling Approach

Cesium loading on the CST was predicted using the ZAM isotherm model developed by the research group of Professor Rayford G. Anthony of Texas A&M University. The ZAM program, named after its developers (i.e., Zheng, Anthony, and Miller), was described in detail in a previous ion exchange study at SRNL.[10] In addition, the OLI Studio™ software (Version 10) from OLI Systems, Inc., was used to estimate feed solution density required as input data to the ZAM program.

There are two options to predict cesium loading.

- Use of an isotherm: An isotherm provides the equilibrium relation between the concentration of cesium loaded on the CST surface to the concentration of cesium in the solution. The isotherm covers a wide range of liquid-phase cesium concentrations. ZAM can generate equilibrium cesium loading data at a given temperature. Generally, an excellent fit for the ZAM data would be achieved by use of the Freundlich/Langmuir isotherm model.
- Variation of ZAM phase ratio: A phase ratio, ϕ, is defined as the ratio of total liquid volume (mL) processed to the mass of CST resin (g_{CST}). To simulate the saturation of cesium loading on CST for a specified feed, ZAM calculations are performed at increasing phase ratios until the calculated equilibrium liquid cesium concentration approximates (usually accurate up to 4 digits) the feed cesium concentration. The corresponding cesium concentration on CST represents the maximum cesium loading.

The two approaches should deliver practically identical results. The methods were discussed in detail in a previous report.[11]

Note that IE-911 and R9120-B (engineered forms of CST) contain inert binder while ZAM data are based on IE-910 (powdered form) and the true-dry mass of CST (i.e., mass remaining at 460 °C). To compare ZAM predictions with test data using engineered CST, a recommended dilution factor of 0.68[10] is frequently applied to account for the binder effect. Additionally, since test data are based on the air-dried mass of CST, an F-factor of 0.8107, determined in the current work for this CST batch,[9] is needed for conversion to the true-dry mass basis.

2.5 Quality Assurance

Requirements for performing reviews of technical reports and the extent of review are established in manual E7 2.60. SRNL documents the extent and type of review using the SRNL Technical Report Design Checklist contained in WSRC-IM-2002-00011, Rev. 2.[12] This work was performed following the applicable TTQAP.[6] The Task Technical Request (TTR) associated with this work[13] requested a functional classification of Safety Class (see section 9.5 of the TTQAP entitled "Clarification of Safety Class Functional Classification"). To match the requested functional classification, this report and calculations within received a technical review by design verification by document review.[14] Data are recorded in the Electronic Laboratory Notebook (ELN) system.[15]

3.0 Results and Discussion

3.1 Tank 10H Interim Samples (HTF-10-21-118 through HTF-10-21-123)

Photographs of the Tank 10H interim samples collected on November 23 and 28, 2021 are provided in Figure 3-1. Samples HTF-10-21-118 (not photographed) and HTF-10-21-121 were clear and colorless, not containing any significant visible solids. HTF-10-21-122 was fairly clear and colorless, although slightly more hazy in appearance than the two surface samples. Sample HTF-10-21-119 appeared brown in color and contained a small amount of visible solids. HTF-10-21-120 was slightly cloudy and appeared to contain a small amount of light-colored solids. Finally, sample HTF-10-21-123 was slightly cloudy and appeared grayish in color.

The densities of the six Tank 10H interim samples are summarized in Table 3-1. The densities of all samples were measured as-received. In the first set of samples (-118 through -120) the percent difference[b] between the highest and lowest densities was approximately 7.5%. For the second set the variation was 4.2%, indicating increased homogeneity in the tank with continued recirculation.

[b] Calculated as (highest density – lowest density)/(average of all three densities) x 100%.

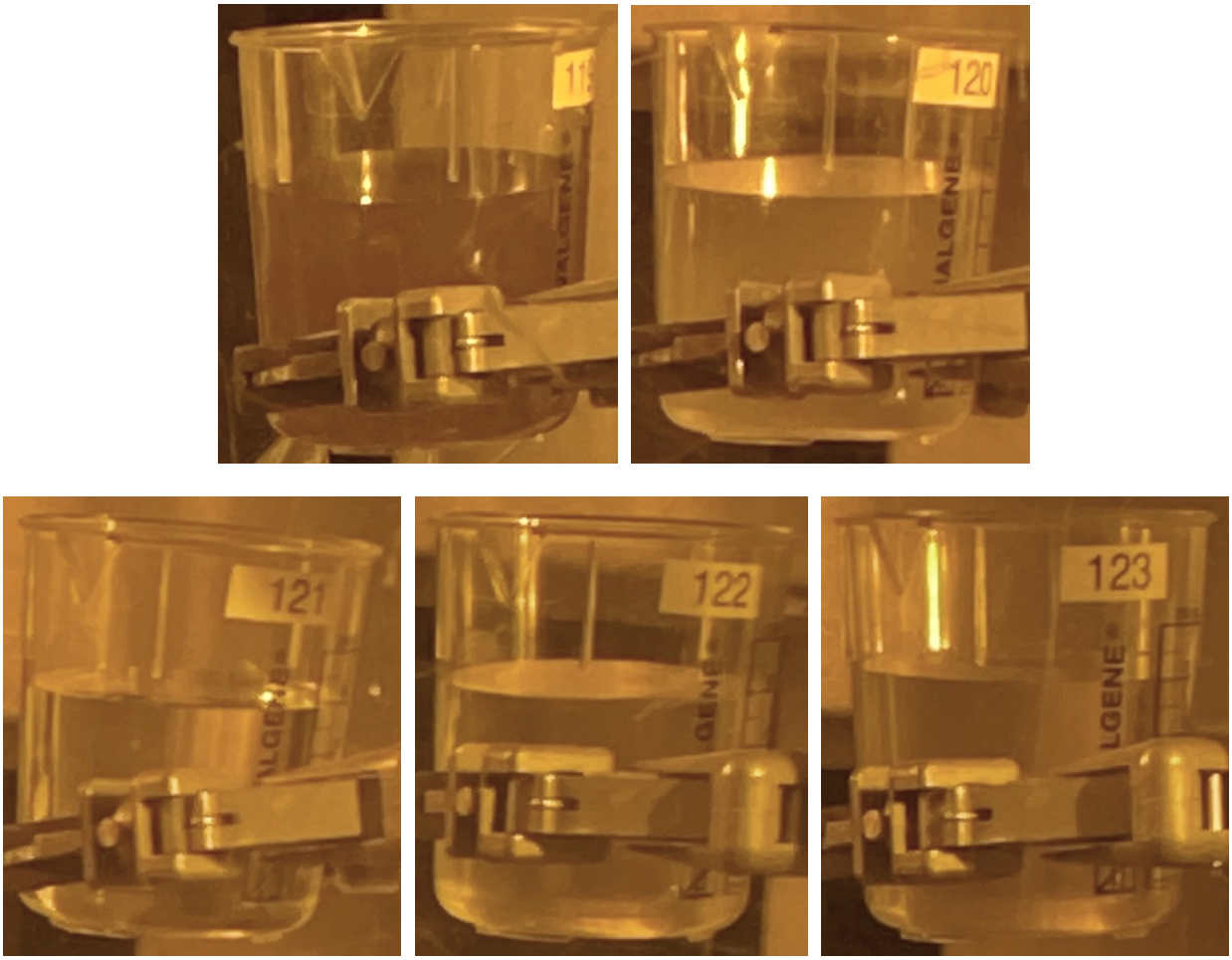

Figure 3-1. Photographs of samples HTF-10-21-119 (top left), HTF-10-21-120 (top right), HTF-10-21-121 (bottom left), HTF-10-21-122 (bottom center), and HTF-10-21-123 (bottom right).

Table 3-1. Density Measurements of Tank 10H Interim Samples

Sample ID	Sample Date	Sample Location	Avg. Density (g/mL)[a]	% RSD[b]
HTF-10-21-118	11/23/21	surface (~122" from tank bottom)	1.271	0.95
HTF-10-21-119	11/23/21	75" from tank bottom	1.364	0.16
HTF-10-21-120	11/23/21	84" from tank bottom	1.266	0.70
HTF-10-21-121	11/28/21	surface (~122" from tank bottom)	1.286	0.25
HTF-10-21-122	11/28/21	84" from tank bottom	1.332	0.64
HTF-10-21-123	11/28/21	70" from tank bottom	1.309	0.00[c]

[a]Temperature during density measurements was 15 °C. [b]Percent relative standard deviation from replicate measurements. [c]Duplicate measurements gave identical results.

3.2 Tank 10H Batch Qualification Samples (HTF-10-21-125, HTF-10-21-126, and HTF-10-21-127)

Photographs of the Tank 10H qualification samples are provided in Figure 3-2. Samples HTF-10-21-125 and HTF-10-21-126 were colorless and did not contain significant visible solids (HTF-10-21-126 was slightly hazy), while sample HTF-10-21-127 appeared gray in color due to the presence of a small amount of suspended dark colored solids.

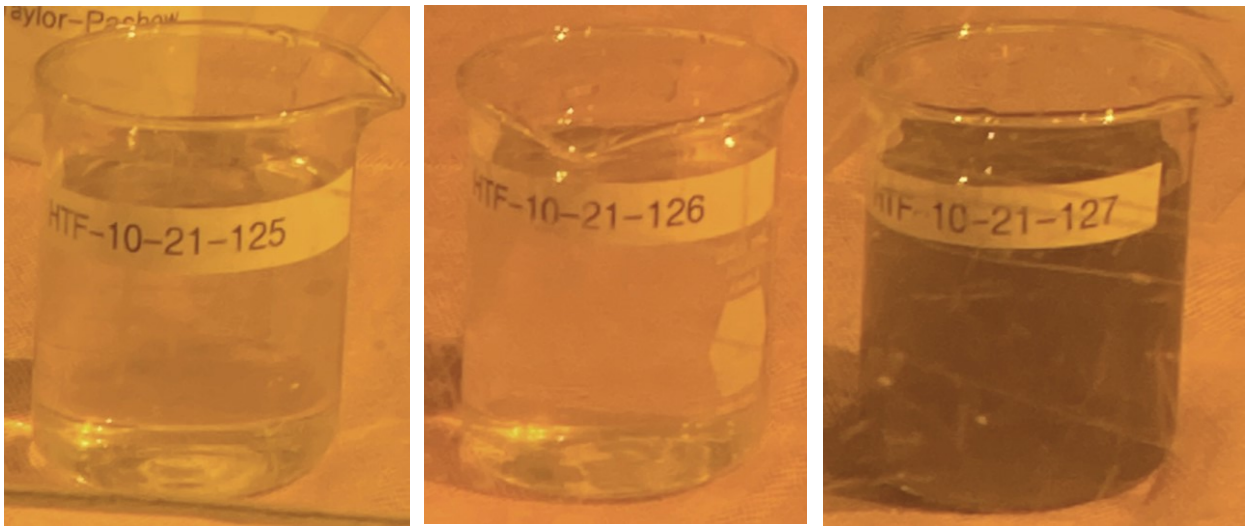

Figure 3-2. Photographs of samples HTF-10-21-125 (left), HTF-10-21-126 (center), and HTF-10-21-127 (right).

The densities of the Tank 10H qualification samples are summarized in Table 3-2. The densities of all samples were measured as-received, and in addition, a portion of sample HTF-10-21-127 was filtered and the density of the filtrate was measured. Based on the density measurements and the corresponding analytical results shown below, it appears that sample HTF-10-21-126 is actually the surface sample as it has the lowest density and sodium concentration. The two sample vials (-125 and -126) could have been switched either on the tank top when collecting the samples or in the Shielded Cells when the samples were transferred from the stainless-steel sample vials into the labeled beakers and polyethylene bottles.

Table 3-2. Density Measurements of Tank 10H Qualification Samples

Sample	Sample Location	Sample Type	Avg. Density (g/mL)[a]	% RSD[b]
HTF-10-21-125	surface (~122" from tank bottom)[c]	as received	1.361	1.68
HTF-10-21-126	98" from tank bottom[c]	as received	1.302	0.61
HTF-10-21-127	70" from tank bottom	filtrate	1.384	0.82
HTF-10-21-127	70" from tank bottom	as received	1.381	0.26

[a]Temperature during density measurements was 17 – 19 °C. [b]Percent relative standard deviation from replicate measurements. [c]Reported locations; however, from the data it appears HTF-10-21-126 is the surface sample.

The inductively coupled plasma – emission spectroscopy (ICP-ES) results of the Tank 10H qualification samples are shown in Tables 3-3 and 3-4. As mentioned above, the ICP-ES results are consistent with the theory that the sample identified as HTF-10-21-126 is the surface sample rather than the 98" depth sample. Sample HTF-10-21-127 (70" depth sample) had the highest concentration of all elements measured via ICP-ES (with exception of Cr), consistent with having the highest density of the three samples. Comparison of the ICP-ES results from the HTF-10-21-127 filtrate to the digested slurry (Table 3-4) shows a significant increase in concentration of the following elements: B, Ca (one replicate sample), Fe, and Mg (one replicate). A summary of the anion concentrations for the qualification samples is shown in Table 3-5. Reasonable agreement between the sum of anions and cations for the three samples was obtained with a 10% difference observed for HTF-10-21-125 and -127, and a 5.8% difference for HTF-10-21-126. In all cases the measured anion concentrations were higher.

Table 3-3. ICP-ES Results for the Tank 10H Batch 1 Qualification Samples (HTF-10-21-125 and -126)

Element	HTF-10-21-125 Avg. (mg/L)	%RSD[a]	HTF-10-21-126 Avg. (mg/L)	%RSD[a]
Ag	< 0.378	n/a	< 0.366	n/a
Al	2715	2.30%	2135	1.79%
B	< 3.01	n/a	< 2.92	n/a
Ba	< 0.261	n/a	< 0.253	n/a
Be	< 0.237	n/a	< 0.230	n/a
Ca	< 1.95	n/a	< 1.90	n/a
Cd	< 0.310	n/a	< 0.300	n/a
Ce	< 9.63	n/a	< 9.34	n/a
Co	< 0.679	n/a	< 0.658	n/a
Cr	25.3	2.24%	17.6	1.93%
Cu	< 1.61	n/a	< 1.56	n/a
Fe	< 1.90	n/a	< 1.85	n/a
Gd	< 1.02	n/a	< 0.99	n/a
K	< 315	n/a	< 306	n/a
La	< 0.628	n/a	< 0.609	n/a
Li	< 8.49	n/a	< 8.23	n/a
Mg	< 1.10	n/a	< 1.07	n/a
Mn	< 1.17	n/a	< 1.13	n/a
Mo	13.9	2.71%	10.0	0.95%
Na	158000	3.79%	125000	3.33%
Nb	< 3.39	n/a	< 3.29	n/a
Ni	< 1.19	n/a	< 1.16	n/a
P	100	1.61%	70.7	1.21%
Pb	< 8.58	n/a	< 8.32	n/a
S	3903	2.67%	2505	1.83%
Sb	< 4.55	n/a	< 4.41	n/a
Si	< 6.15	n/a	< 5.96	n/a
Sn	< 28.6	n/a	< 27.7	n/a
Sr	< 0.532	n/a	< 0.516	n/a
Th	< 14.2	n/a	< 13.8	n/a
Ti	< 5.69	n/a	< 5.52	n/a
U	< 11.8	n/a	< 11.5	n/a
V	< 5.73	n/a	< 5.56	n/a
Zn	< 0.794	n/a	< 0.770	n/a
Zr	< 0.761	n/a	< 0.739	n/a

[a]Percent relative standard deviation from duplicate samples. The reported method uncertainty ranged from 10 to 10.9%.

Table 3-4. ICP-ES Results for the Tank 10H Batch 1 Qualification Sample HTF-10-21-127 (Filtrate and Digested Slurry)

Element	HTF-10-21-127 Filtrate Avg. (mg/L)	%RSD[a]	HTF-10-21-127 Digested Slurry Avg. (mg/L)	%RSD[a]	% Difference[b]
Ag	< 0.381	n/a	< 0.306	n/a	n/a
Al	3050	0.42%	3251	3.30%	6.58%
B	< 3.03	n/a	86.5	11.4%	> 2750%
Ba	< 0.263	n/a	< 0.9001	n/a	n/a
Be	< 0.239	n/a	< 0.1919	n/a	n/a
Ca	< 1.97	n/a	141[c]	n/a	> 7046%
Cd	< 0.312	n/a	< 0.431	n/a	n/a
Ce	< 9.71	n/a	< 4.94	n/a	n/a
Co	< 0.685	n/a	< 0.549	n/a	n/a
Cr	23.5	0.21%	27.5	2.84%	17%
Cu	< 1.62	n/a	< 5.90	n/a	n/a
Fe	< 1.92	n/a	28.0	43.6%	> 1356%
Gd	< 1.03	n/a	< 0.8297	n/a	n/a
K	< 318	n/a	< 325	n/a	n/a
La	< 0.634	n/a	< 0.409	n/a	n/a
Li	< 8.56	n/a	< 6.87	n/a	n/a
Mg	< 1.11	n/a	39.6[d]	n/a	> 3469%
Mn	< 1.17	n/a	1.74	15.7%	48.1%
Mo	14.1	0.39%	15.1	1.94%	6.98%
Na	161000	0.86%	169802	2.30%	5.50%
Nb	< 3.42	n/a	< 2.75	n/a	n/a
Ni	< 1.20	n/a	< 1.064	n/a	n/a
P	108.5	1.06%	112.9	1.12%	4.05%
Pb	< 8.65	n/a	< 6.95	n/a	n/a
S	4856	0.58%	4970	1.57%	2.33%
Sb	< 4.59	n/a	< 3.69	n/a	n/a
Si	< 6.20	n/a	< 146	n/a	n/a
Sn	< 28.8	n/a	< 15.1	n/a	n/a
Sr	< 0.537	n/a	< 1.064	n/a	n/a
Th	< 14.3	n/a	< 3.70	n/a	n/a
Ti	< 5.74	n/a	< 2.63	n/a	n/a
U	< 11.9	n/a	< 9.58	n/a	n/a
V	< 5.78	n/a	< 4.65	n/a	n/a
Zn	< 0.800	n/a	< 1.370	n/a	n/a
Zr	< 0.768	n/a	< 0.618	n/a	n/a

[a]Percent relative standard deviation from duplicate samples. The reported method uncertainty ranged from 10 to 11.3% (2 sigma). [b]% Difference is defined here as (slurry – filtrate)/filtrate x 100%. [c]Single replicate above the detection limit. The replicate sample was < 10.7 mg/L. [d]Single replicate above the detection limit. The replicate sample was < 0.843 mg/L.

Table 3-5. Anion and Carbon Results for the Tank 10H Batch 1 Qualification Samples (HTF-10-21-125, -126, and -127)

Analyte	HTF-10-21-125	%RSD[a]	HTF-10-21-126	%RSD[a]	HTF-10-21-127 Filtrate	%RSD[a]
$Al(OH)_4^-$ (M)[b]	0.101	2.30%	7.91E-02	1.79%	0.113	0.416%
Free OH^- (M)	0.367	10.3%	0.562[c]	12.1%	0.361	5.64%
NO_3^- (M)	4.60	1.24%	3.25	2.26%	4.63[d]	0.315%[d]
SO_4^{2-} (M)	0.131	0.951%	0.0791	5.92%	0.154[d]	0.0196%[d]
NO_2^- (M)	0.603	0.520%	0.423	2.06%	0.653[d]	0.126%[d]
F^- (M)	< 2.03E-02	n/a	< 2.33E-02	n/a	< 2.44E-02	n/a
Cl^- (M)	< 1.09E-02	n/a	< 1.25E-02	n/a	< 1.30E-02	n/a
Br^- (M)	< 2.41E-02	n/a	< 2.77E-02	n/a	< 2.90E-02	n/a
HCO_2^- (M)	< 8.55E-03	n/a	< 9.82E-03	n/a	< 1.03E-02	n/a
PO_4^{3-} (M)	< 4.06E-03	n/a	< 4.65E-03	n/a	< 4.87E-03	n/a
$C_2O_4^{2-}$ (M)	4.65E-03[e]	n/a	< 5.02E-02	n/a	< 5.26E-03	n/a
CO_3^{2-} (M)	0.836	1.18%	0.653	1.39%	0.851	0.439%
TOC (mg/L)	194	0.778%	148	1.12%	189	3.09%

[a]Percent relative standard deviation from duplicate samples. The reported method uncertainty is 10% at 1 sigma for IC anions and 2 sigma for free hydroxide and TIC/TOC results. [b]Based on aluminum concentration measured by ICP-ES (Table 3-3 and 3-4) [c]Results of repeat analysis with larger sample size for the titration. [d]Repeat analysis resulted in slightly different results than reported in the earlier memo.[3] [e]Single replicate above the method detection limit. The duplicate sample was < 5.23E-03 M.

Gamma spectroscopy and liquid scintillation counting (LSC), with and without Cs removal, were performed on the three qualification samples and the results are summarized in Table 3-6. The alpha activity (with and without Cs removal) was below the detection limit in all samples. The ^{137}Cs activity in the as-received HTF-10-21-127 was slightly higher than measured in the filtrate of the same sample. A similar difference was observed in the beta activities. However, the beta activity after Cs removal showed an increase in activity of almost an order of magnitude indicating the presence of other beta emitters (non-Cs) in the solids present in HTF-10-21-127. A summary of other radionuclide activities in the Tank 10H qualification samples is provided in Table 3-7.

Table 3-6. Alpha, Beta and Gamma Activities in Tank 10H Qualification Samples[a]

	^{137}Cs (dpm/mL)	Alpha Activity (dpm/mL)	Beta Activity (dpm/mL)	Cs Removed	
				Alpha Activity (dpm/mL)	Beta Activity (dpm/mL)
HTF-10-21-125	2.65E+08 (3.31% RSD)	< 1.40E+07	3.35E+08 (1.69% RSD)	< 4.61E+04	9.30E+05 (1.06% RSD)
HTF-10-21-126	1.85E+08 (3.99% RSD)	< 1.26E+07	2.39E+08 (6.10% RSD)	< 2.36E+04	4.67E+05 (1.08% RSD)
HTF-10-21-127 Filtrate	2.62E+08 (5.54% RSD)	< 1.31E+07	3.35E+08 (0.0144% RSD)	< 1.91E+04	4.93E+05 (0.685% RSD)
HTF-10-21-127 Slurry	2.85E+08 (1.03% RSD)	< 5.63E+07	3.53E+08 (4.42% RSD)	< 1.02E+05	4.16E+06 (5.39% RSD)

[a]The %RSD is the relative standard deviation of duplicate measurements. The reported method uncertainties are 5% for gamma and 10-12% for beta at 1 sigma.

Table 3-7. Summary of Radionuclides Measured in the Tank 10H Batch 1 Qualification Samples (HTF-10-21-125, -126, and -127)

Radionuclide	HTF-10-21-125 (dpm/mL)	%RSD[a] (Avg. Method Unc.)	HTF-10-21-126 (dpm/mL)	%RSD[a] (Avg. Method Unc.)	HTF-10-21-127 Filtrate (dpm/mL)	%RSD[a] (Avg. Method Unc.)
^{60}Co	< 2.83E+01	n/a (MDA[b])	< 2.38E+01	n/a (MDA)	< 2.52E+01	n/a (MDA)
^{90}Sr	3.59E+05	0.612% (40.0%)	1.03E+05	25.8% (39.0%)	8.72E+04	18.6% (35.4%)
^{99}Tc	1.23E+05	7.79% (11.3%)	8.28E+04	3.46% (11.2%)	1.15E+05	6.34% (11.5%)
^{106}Ru	< 2.35E+02	n/a (MDA)	< 2.10E+02	n/a (MDA)	< 2.44E+02	n/a (MDA)
^{125}Sb	< 1.69E+02	n/a (MDA)	< 1.31E+02	n/a (MDA)	< 1.50E+02	n/a (MDA)
^{126}Sb	3.68E+02	1.52% (5.00%)	2.61E+02	1.01% (5.00%)	3.69E+02	1.51% (5.00%)
^{126}Sn	3.68E+02	1.52% (5.00%)	2.61E+02	1.01% (5.00%)	3.69E+02	1.51% (5.00%)
^{129}I	< 8.09E+00	n/a (Upper Limit/MDA)	< 2.37E+00	n/a (MDA)	< 4.73E+00	n/a (Upper Limit/MDA)
^{144}Ce	< 3.06E+02	n/a (MDA)	< 2.37E+02	n/a (MDA)	< 2.51E+02	n/a (MDA)
^{154}Eu	< 8.36E+01	n/a (MDA)	< 6.35E+01	n/a (MDA)	< 6.73E+01	n/a (MDA)
^{238}Pu	4.29E+04	1.84% (6.12%)	2.23E+04	0.585% (6.40%)	1.53E+04	3.45% (6.79%)
$^{239/240}$Pu	6.36E+02	0.415% (10.8%)	3.54E+02	0.316% (11.7%)	1.84E+02	46.8% (29.2%)
^{241}Pu	4.98E+03	24.7% (16.5%)	2.39E+03	13.9% (18.4%)	2.13E+03[c]	n/a (18.4%)
^{241}Am	1.79E+02	7.70% (7.99%)	<7 .17E+01	n/a (MDA)	< 9.89E+01	n/a (MDA)

[a]The %RSD is based on the standard deviation of duplicate samples. [b]MDA = minimum detectable activity. [c]Single replicate above the detection limit. The duplicate sample was < 1.18E+04 dpm/mL.

The isotopic distribution of Cs based on the mass spectrometry results of the qualification samples is provided in Table 3-8. The isotopic ratios for HTF-10-21-125 and HTF-10-21-126 were in good agreement; however, the ^{137}Cs content in HTF-10-21-127 filtrate appeared low based on the inductively coupled plasma – mass spectrometry (ICP-MS) data. The isotopic distribution data for the digested HTF-10-21-127 slurry were in closer agreement with the results for HTF-10-21-125 and -126. There are two methods for calculating the total Cs. The first involves using the isotopic ratios from the ICP-MS data and the ^{137}Cs activity from the gamma data (approached used in the past); while the second is simply a sum of the Cs isotope masses from the ICP-MS data. Using the first method may bias the value high for HTF-10-21-127 filtrate sample due to the seemingly low ^{137}Cs mass fraction; and therefore, it is recommended that the average from the two different methods be used to represent the total Cs. The total Cs concentrations calculated using both methods, along with the average values, are provided in Table 3-9. The full suites of ICP-MS results are provided in Tables 3-10 through 3-13.

Table 3-8. Cs Isotopes from ICP-MS for the Tank 10H Qualification Samples

HTF-10-21-125				
Isotope	**Mean Concentration (mg/L)**	**%RSD[a]**	**Isotopic Distribution, Mass %**	**Mole Fraction**
Cs-133	6.14	1.31	76.7	0.772
Cs-134	< 4.17E-03	n/a	< 0.05	< 5.20E-04
Cs-135	0.586	1.16	7.32	0.0725
Cs-137	1.28	0.592	16.0	0.156
HTF-10-21-126				
Isotope	**Mean Concentration (mg/L)**	**%RSD[a]**	**Isotopic Distribution, Mass %**	**Mole Fraction**
Cs-133	4.47	1.21	76.8	0.772
Cs-134	< 4.45E-03	n/a	< 0.08	< 7.63E-04
Cs-135	0.428	2.92	7.35	0.0728
Cs-137	0.923	0.288	15.9	0.155
HTF-10-21-127				
Isotope	**Mean Concentration (mg/L)**	**%RSD[a]**	**Isotopic Distribution, Mass %**	**Mole Fraction**
Cs-133	6.19	0.640	78.2	0.786
Cs-134	< 4.63E-03	n/a	< 0.06	< 5.83E-04
Cs-135	0.588	0.312	7.43	0.0736
Cs-137	1.14	0.322	14.3	0.140
HTF-10-21-127 Slurry				
Isotope	**Mean Concentration (mg/L)**	**%RSD[a]**	**Isotopic Distribution, Mass %**	**Mole Fraction**
Cs-133	6.09	0.597	76.5	0.769
Cs-134	1.32E-02[b]	n/a	0.165	1.65E-03
Cs-135	0.580	6.09	7.29	0.0722
Cs-137	1.28	4.73	16.1	0.157

[a]Percent relative standard deviation from duplicate samples. The reported method uncertainty is 20% at two sigma. [b]Single replicate above the detection limit.

Table 3-9. Total Cs in the Tank 10H Qualification Samples

	Total Cs Concentration			
	Gamma/Isotopic Ratio (mg/L)	**Sum of Isotopes by ICP-MS (mg/L)**	**Average (mg/L)**	**Average (M)**
HTF-10-21-125	8.59	8.00	8.30 (5.02% RSD)	6.20E-05 (5.01% RSD)
HTF-10-21-126	6.06	5.82	5.94 (2.79% RSD)	4.44E-05 (2.79% RSD)
HTF-10-21-127 Filtrate	9.45	7.91	8.68 (12.5% RSD)	6.49E-05 (12.5% RSD)
HTF-10-21-127 Slurry	9.18	7.96	8.57 (10.1% RSD)	6.41E-05 (10.1% RSD)

Table 3-10. ICP-MS Results for Tank 10H Batch 1 Qualification Sample HTF-10-21-125

m/z	Avg. Conc. (µg/L)	% RSD[a]	m/z	Avg. Conc. (µg/L)	% RSD[a]	m/z	Avg. Conc. (µg/L)	% RSD[a]
59	< 4.59E+01	n/a	**134**	< 4.59E+00	n/a	**180**	< 4.59E+00	n/a
84	< 4.59E+00	n/a	**135**	5.87E+02	1.16%	**181**	< 4.59E+00	n/a
85	7.65E+02	0.995%	**136**	< 4.59E+00	n/a	**182**	5.16E+01	0.891%
86	< 4.59E+00	n/a	**137**	1.28E+03	0.592%	**183**	2.97E+01	5.45%
87	1.67E+03	0.623%	**138**	1.24E+01	4.84%	**184**	6.21E+01	1.49%
88	3.26E+01	1.24%	**139**	< 4.59E+00	n/a	**185**	< 4.59E+00	n/a
89	< 4.59E+00	n/a	**140**	2.54E+01	31.6%	**186**	5.81E+01	2.64%
90	7.12E+00	13.7%	**141**	< 4.59E+00	n/a	**187**	< 4.59E+00	n/a
91	5.66E+00[b]	n/a	**142**	8.14E+00	42.57%	**188**	< 4.59E+00	n/a
92	7.95E+01	0.580%	**143**	4.90E+00[b]	n/a	**189**	< 4.59E+00	n/a
93	7.84E+00	23.7%	**144**	5.64E+00[b]	n/a	**191**	< 4.59E+00	n/a
94	5.55E+01	0.911%	**145**	< 4.59E+00	n/a	**193**	< 4.59E+00	n/a
95	4.35E+03	0.890%	**146**	< 4.59E+00	n/a	**194**	< 4.59E+00	n/a
96	9.63E+01	2.80%	**147**	< 4.59E+00	n/a	**195**	< 4.59E+00	n/a
97	4.14E+03	1.32%	**148**	< 4.59E+00	n/a	**196**	1.18E+01	2.73%
98	4.11E+03	1.61%	**149**	< 4.59E+00	n/a	**198**	6.17E+02	0.343%
99	2.50E+03	1.10%	**150**	< 4.59E+00	n/a	**203**	< 4.59E+00	n/a
100	4.29E+03	1.79%	**151**	< 4.59E+00	n/a	**204**	3.22E+02	0.120%
101	2.49E+02	0.916%	**152**	< 4.59E+00	n/a	**205**	< 4.59E+00	n/a
102	2.15E+02	1.87%	**153**	< 4.59E+00	n/a	**206**	2.91E+02	0.358%
103	5.56E+02	0.820%	**154**	< 4.59E+00	n/a	**207**	2.49E+02	0.390%
104	1.13E+02	0.0175%	**155**	< 4.59E+00	n/a	**208**	6.09E+02	0.321%
105	< 4.59E+01	n/a	**156**	< 4.59E+00	n/a	**229**	< 4.59E+00	n/a
106	< 4.59E+01	n/a	**157**	< 4.59E+00	n/a	**230**	< 4.59E+00	n/a
107	< 4.59E+01	n/a	**158**	< 4.59E+00	n/a	**232**	9.11E+01	35.9%
108	4.79E+00[c]	n/a	**159**	< 4.59E+00	n/a	**233**	6.49E+00	9.43%
109	9.45E+00	6.60%	**160**	< 4.59E+00	n/a	**234**	< 4.59E+00	n/a
110	< 4.59E+00	n/a	**161**	< 4.59E+00	n/a	**235**	5.04E+01	8.33%
111	< 4.59E+00	n/a	**162**	< 4.59E+00	n/a	**236**	1.41E+01	9.94%
112	7.81E+00	6.59%	**163**	< 4.59E+00	n/a	**237**	1.31E+01	4.47%
113	< 4.59E+00	n/a	**164**	< 4.59E+00	n/a	**238**	7.17E+02	18.2%
114	7.02E+00	1.49%	**165**	< 4.59E+00	n/a	**239**	< 4.59E+00	n/a
116	1.09E+02	2.27%	**166**	< 4.59E+00	n/a	**240**	< 4.59E+00	n/a
117	7.42E+01	0.599%	**167**	< 4.59E+00	n/a	**241**	< 4.59E+00	n/a
118	2.14E+02	0.0782%	**168**	< 4.59E+00	n/a	**242**	< 4.59E+00	n/a
119	7.86E+01	1.63%	**169**	< 4.59E+00	n/a	**243**	< 4.59E+00	n/a
120	2.91E+02	2.10%	**170**	< 4.59E+00	n/a	**244**	< 4.59E+00	n/a
121	< 4.59E+00	n/a	**171**	< 4.59E+00	n/a	**245**	< 4.59E+00	n/a
122	7.81E+01	2.16%	**172**	< 4.59E+00	n/a	**246**	< 4.59E+00	n/a
123	< 4.59E+00	n/a	**173**	< 4.59E+00	n/a	**247**	< 4.59E+00	n/a
124	1.18E+02	1.74%	**174**	< 4.59E+00	n/a	**248**	< 4.59E+00	n/a
125	< 4.59E+00	n/a	**175**	< 4.59E+00	n/a	**249**	< 4.59E+00	n/a
126	3.92E+02	4.46%	**176**	< 4.59E+00	n/a	**250**	< 4.59E+00	n/a
128	< 4.59E+00	n/a	**177**	< 4.59E+00	n/a	**251**	< 4.59E+00	n/a
130	< 4.59E+00	n/a	**178**	< 4.59E+00	n/a			
133	6.14E+03	1.31%	**179**	< 4.59E+00	n/a			

[a]The %RSD is based on the standard deviation of duplicate samples. The reported method uncertainty is 20% at two sigma. [b]Single result above the method detection limit. The duplicate sample had a reported concentration of < 4.58E+00 µg/L. [c]Single result above the method detection limit. The duplicate sample had a reported concentration of < 4.60E+00 µg/L.

Table 3-11. ICP-MS Results for Tank 10H Batch 1 Qualification Sample HTF-10-21-126

m/z	Avg. Conc. (µg/L)	% RSD[a]	m/z	Avg. Conc. (µg/L)	% RSD[a]	m/z	Avg. Conc. (µg/L)	% RSD[a]
59	< 4.45E+01	n/a	**134**	< 4.45E+00	n/a	**180**	< 4.45E+00	n/a
84	< 4.45E+00	n/a	**135**	4.28E+02	2.92%	**181**	< 4.45E+00	n/a
85	5.60E+02	1.81%	**136**	< 4.45E+00	n/a	**182**	4.02E+01	15.8%
86	< 4.45E+00	n/a	**137**	9.23E+02	0.288%	**183**	2.24E+01	15.5%
87	1.22E+03	0.587%	**138**	< 1.11E+01	n/a	**184**	4.79E+01	14.7%
88	2.43E+01	5.98%	**139**	< 4.45E+00	n/a	**185**	< 4.45E+00	n/a
89	< 4.45E+00	n/a	**140**	< 4.45E+00	n/a	**186**	4.56E+01	15.1%
90	4.56E+00[b]	n/a	**141**	< 4.45E+00	n/a	**187**	< 4.45E+00	n/a
91	< 4.45E+00	n/a	**142**	< 4.45E+00	n/a	**188**	< 4.45E+00	n/a
92	5.66E+01	0.111%	**143**	< 4.45E+00	n/a	**189**	< 4.45E+00	n/a
93	5.31E+00	2.15%	**144**	< 4.45E+00	n/a	**191**	< 4.45E+00	n/a
94	3.75E+01	2.13%	**145**	< 4.45E+00	n/a	**193**	< 4.45E+00	n/a
95	2.97E+03	3.84%	**146**	< 4.45E+00	n/a	**194**	< 4.45E+00	n/a
96	6.73E+01	0.907%	**147**	< 4.45E+00	n/a	**195**	< 4.45E+00	n/a
97	2.89E+03	4.99%	**148**	< 4.45E+00	n/a	**196**	6.61E+00	5.86%
98	2.86E+03	1.09%	**149**	< 4.45E+00	n/a	**198**	2.97E+02	0.894%
99	1.81E+03	0.476%	**150**	< 4.45E+00	n/a	**203**	< 4.45E+00	n/a
100	2.99E+03	2.10%	**151**	< 4.45E+00	n/a	**204**	1.57E+02	1.75%
101	1.81E+02	0.895%	**152**	< 4.45E+00	n/a	**205**	< 4.45E+00	n/a
102	1.61E+02	1.52%	**153**	< 4.45E+00	n/a	**206**	2.24E+02	1.18%
103	3.92E+02	1.21%	**154**	< 4.45E+00	n/a	**207**	1.95E+02	0.780%
104	8.44E+01	0.329%	**155**	< 4.45E+00	n/a	**208**	4.70E+02	0.0393%
105	< 4.45E+01	n/a	**156**	< 4.45E+00	n/a	**229**	< 4.45E+00	n/a
106	< 4.45E+01	n/a	**157**	< 4.45E+00	n/a	**230**	< 4.45E+00	n/a
107	< 4.45E+01	n/a	**158**	< 4.45E+00	n/a	**232**	9.99E+00	7.88%
108	< 4.45E+00	n/a	**159**	< 4.45E+00	n/a	**233**	< 4.45E+00	n/a
109	< 4.45E+00	n/a	**160**	< 4.45E+00	n/a	**234**	< 4.45E+00	n/a
110	< 4.45E+00	n/a	**161**	< 4.45E+00	n/a	**235**	2.55E+01	0.957%
111	< 4.45E+00	n/a	**162**	< 4.45E+00	n/a	**236**	7.14E+00	4.89%
112	5.07E+00	4.73%	**163**	< 4.45E+00	n/a	**237**	6.65E+00	2.81%
113	< 4.45E+00	n/a	**164**	< 4.45E+00	n/a	**238**	3.02E+02	0.501%
114	5.90E+00	1.97%	**165**	< 4.45E+00	n/a	**239**	< 4.45E+00	n/a
116	7.65E+01	0.207%	**166**	< 4.45E+00	n/a	**240**	< 4.45E+00	n/a
117	5.37E+01	1.20%	**167**	< 4.45E+00	n/a	**241**	< 4.45E+00	n/a
118	1.54E+02	0.947%	**168**	< 4.45E+00	n/a	**242**	< 4.45E+00	n/a
119	5.35E+01	3.56%	**169**	< 4.45E+00	n/a	**243**	< 4.45E+00	n/a
120	2.10E+02	1.47%	**170**	< 4.45E+00	n/a	**244**	< 4.45E+00	n/a
121	< 4.45E+00	n/a	**171**	< 4.45E+00	n/a	**245**	< 4.45E+00	n/a
122	5.47E+01	2.82%	**172**	< 4.45E+00	n/a	**246**	< 4.45E+00	n/a
123	< 4.45E+00	n/a	**173**	< 4.45E+00	n/a	**247**	< 4.45E+00	n/a
124	8.51E+01	0.116%	**174**	< 4.45E+00	n/a	**248**	< 4.45E+00	n/a
125	< 4.45E+00	n/a	**175**	< 4.45E+00	n/a	**249**	< 4.45E+00	n/a
126	2.78E+02	2.82%	**176**	< 4.45E+00	n/a	**250**	< 4.45E+00	n/a
128	< 4.45E+00	n/a	**177**	< 4.45E+00	n/a	**251**	< 4.45E+00	n/a
130	< 4.45E+00	n/a	**178**	< 4.45E+00	n/a			
133	4.47E+03	1.21%	**179**	< 4.45E+00	n/a			

[a]The %RSD is based on the standard deviation of duplicate samples. The reported method uncertainty is 20% at two sigma. [b]Single result above the method detection limit. The duplicate sample had a reported concentration of < 4.44E+00 µg/L.

Table 3-12. ICP-MS Results for Tank 10H Batch 1 Qualification Sample HTF-10-21-127 Filtrate

m/z	Avg. Conc. (µg/L)	% RSD[a]	m/z	Avg. Conc. (µg/L)	% RSD[a]	m/z	Avg. Conc. (µg/L)	% RSD[a]
59	< 4.63E+01	n/a	**134**	< 4.63E+00	n/a	**180**	< 4.63E+00	n/a
84	< 4.63E+00	n/a	**135**	5.88E+02	0.312%	**181**	< 4.63E+00	n/a
85	7.76E+02	1.86%	**136**	< 4.63E+00	n/a	**182**	5.10E+01	3.43%
86	< 4.63E+00	n/a	**137**	1.14E+03	0.322%	**183**	3.45E+01	24.8%
87	1.69E+03	0.734%	**138**	< 1.16E+01	n/a	**184**	5.88E+01	4.79%
88	2.52E+01	5.71%	**139**	< 4.63E+00	n/a	**185**	< 4.63E+00	n/a
89	< 4.63E+00	n/a	**140**	< 4.63E+00	n/a	**186**	5.58E+01	2.16%
90	< 4.63E+00	n/a	**141**	< 4.63E+00	n/a	**187**	< 4.63E+00	n/a
91	< 4.63E+00	n/a	**142**	< 4.63E+00	n/a	**188**	< 4.63E+00	n/a
92	7.81E+01	0.359%	**143**	< 4.63E+00	n/a	**189**	< 4.63E+00	n/a
93	< 4.63E+00	n/a	**144**	< 4.63E+00	n/a	**191**	< 4.63E+00	n/a
94	5.13E+01	0.130%	**145**	< 4.63E+00	n/a	**193**	< 4.63E+00	n/a
95	4.13E+03	1.01%	**146**	< 4.63E+00	n/a	**194**	< 4.63E+00	n/a
96	9.53E+01	3.74%	**147**	< 4.63E+00	n/a	**195**	< 4.63E+00	n/a
97	4.05E+03	0.846%	**148**	< 4.63E+00	n/a	**196**	8.33E+00	2.42%
98	4.15E+03	0.684%	**149**	< 4.63E+00	n/a	**198**	4.02E+02	0.329%
99	2.40E+03	0.731%	**150**	< 4.63E+00	n/a	**203**	< 4.63E+00	n/a
100	4.36E+03	0.225%	**151**	< 4.63E+00	n/a	**204**	2.07E+02	0.899%
101	2.80E+02	0.537%	**152**	< 4.63E+00	n/a	**205**	< 4.63E+00	n/a
102	2.47E+02	2.28%	**153**	< 4.63E+00	n/a	**206**	1.70E+02	0.261%
103	5.83E+02	1.03%	**154**	< 4.63E+00	n/a	**207**	1.48E+02	0.364%
104	1.31E+02	1.12%	**155**	< 4.63E+00	n/a	**208**	3.59E+02	1.16%
105	< 5.55E+01	n/a	**156**	< 4.63E+00	n/a	**229**	< 4.63E+00	n/a
106	< 5.55E+01	n/a	**157**	< 4.63E+00	n/a	**230**	< 4.63E+00	n/a
107	< 5.55E+01	n/a	**158**	< 4.63E+00	n/a	**232**	< 4.63E+00	n/a
108	< 5.55E+00	n/a	**159**	< 4.63E+00	n/a	**233**	5.59E+00	0.0726%
109	< 4.63E+00	n/a	**160**	< 4.63E+00	n/a	**234**	< 4.63E+00	n/a
110	< 4.63E+00	n/a	**161**	< 4.63E+00	n/a	**235**	4.39E+01	0.785%
111	< 4.63E+00	n/a	**162**	< 4.63E+00	n/a	**236**	1.25E+01	0.308%
112	7.83E+00	1.45%	**163**	< 4.63E+00	n/a	**237**	1.75E+01	1.22%
113	< 4.63E+00	n/a	**164**	< 4.63E+00	n/a	**238**	3.76E+02	0.677%
114	7.67E+00	9.33%	**165**	< 4.63E+00	n/a	**239**	< 4.63E+00	n/a
116	1.07E+02	2.36%	**166**	< 4.63E+00	n/a	**240**	< 4.63E+00	n/a
117	7.30E+01	3.10%	**167**	< 4.63E+00	n/a	**241**	< 4.63E+00	n/a
118	2.14E+02	0.440%	**168**	< 4.63E+00	n/a	**242**	< 4.63E+00	n/a
119	7.40E+01	1.62%	**169**	< 4.63E+00	n/a	**243**	< 4.63E+00	n/a
120	2.91E+02	0.0317%	**170**	< 4.63E+00	n/a	**244**	< 4.63E+00	n/a
121	< 4.63E+00	n/a	**171**	< 4.63E+00	n/a	**245**	< 4.63E+00	n/a
122	7.63E+01	0.904%	**172**	< 4.63E+00	n/a	**246**	< 4.63E+00	n/a
123	< 4.63E+00	n/a	**173**	< 4.63E+00	n/a	**247**	< 4.63E+00	n/a
124	1.21E+02	0.446%	**174**	< 4.63E+00	n/a	**248**	< 4.63E+00	n/a
125	< 4.63E+00	n/a	**175**	< 4.63E+00	n/a	**249**	< 4.63E+00	n/a
126	3.99E+02	0.728%	**176**	< 4.63E+00	n/a	**250**	< 4.63E+00	n/a
128	< 4.63E+00	n/a	**177**	< 4.63E+00	n/a	**251**	< 4.63E+00	n/a
130	< 4.63E+00	n/a	**178**	< 4.63E+00	n/a			
133	6.19E+03	0.640%	**179**	< 4.63E+00	n/a			

[a]The %RSD is based on the standard deviation of duplicate samples. The reported method uncertainty is 20% at two sigma.

Table 3-13. ICP-MS Results for Tank 10H Batch 1 Qualification Sample HTF-10-21-127 Slurry

m/z	Avg. Conc. (µg/L)	% RSD[a]	% Change from Filtrate	m/z	Avg. Conc. (µg/L)	% RSD[a]	% Change from Filtrate	m/z	Avg. Conc. (µg/L)	% RSD[a]	% Change from Filtrate
59	2.33E+01	60.0%	n/a	**134**	2.56E+01[b]	n/a	> 454%	**180**	< 7.43E+00	n/a	n/a
84	< 7.43E+00	n/a	n/a	**135**	6.14E+02	6.09%	4.43%	**181**	< 7.43E+00	n/a	n/a
85	7.79E+02	0.0735%	0.341%	**136**	3.52E+01	107%	> 662%	**182**	7.52E+01	20.6%	47.6%
86*	7.50E+01[b]	n/a	> 1521%	**137**	1.34E+03	4.73%	17.8%	**183**	4.13E+01	16.7%	19.9%
87	1.72E+03	3.19%	1.99%	**138**	3.70E+02	97.6%	> 3097%	**184**	9.01E+01	17.2%	53.2%
88	3.78E+02	117%	1402%	**139**	5.14E+01	12.3%	> 1012%	**185**	< 7.43E+00	n/a	n/a
89	2.25E+01	8.30%	> 387%	**140**	2.16E+02	6.86%	> 4573%	**186**	8.37E+01	22.4%	50.0%
90	7.90E+01	78.4%	> 1609%	**141**	4.00E+01	4.67%	> 764%	**187**	< 7.43E+00	n/a	n/a
91	3.45E+01	40.5%	> 646%	**142**	6.63E+01	7.75%	> 1334%	**188**	< 7.43E+00	n/a	n/a
92	1.31E+02	19.0%	67.2%	**143**	3.63E+01	1.13%	> 684%	**189**	< 7.43E+00	n/a	n/a
93	3.64E+01	7.18%	> 686%	**144**	4.03E+01	6.99%	> 771%	**191**	1.04E+01	3.87%	> 125%
94	1.02E+02	25.4%	98.9%	**145**	2.54E+01	3.05%	> 448%	**193**	1.66E+01	6.86%	> 260%
95	4.57E+03	1.74%	10.6%	**146**	2.14E+01	6.85%	> 364%	**194**	< 7.43E+00	n/a	n/a
96	1.34E+02	6.20%	40.7%	**147**	1.28E+01	3.22%	> 178%	**195**	< 7.43E+00	n/a	n/a
97	4.39E+03	1.65%	8.41%	**148**	1.32E+01	6.46%	> 185%	**196**	2.18E+01	5.60%	161%
98	4.38E+03	1.34%	5.50%	**149**	< 7.43E+00	n/a	n/a	**198**	1.33E+03	1.27%	231%
99	2.52E+03	1.93%	4.93%	**150**	1.21E+01	4.08%	> 162%	**203**	< 7.43E+00	n/a	n/a
100	4.57E+03	0.0827%	4.80%	**151**	< 7.43E+00	n/a	n/a	**204**	6.83E+02	0.332%	230%
101	3.70E+02	2.32%	32.4%	**152**	< 7.43E+00	n/a	n/a	**205**	< 7.43E+00	n/a	n/a
102	3.26E+02	1.71%	32.4%	**153**	< 7.43E+00	n/a	n/a	**206**	3.46E+02	20.0%	103%
103	6.59E+02	0.908%	13.2%	**154**	< 7.43E+00	n/a	n/a	**207**	3.05E+02	23.3%	106%
104	2.30E+02	3.09%	75.0%	**155**	< 7.43E+00	n/a	n/a	**208**	7.35E+02	22.1%	105%
105	3.10E+02	10.6%	> 458%	**156**	< 7.43E+00	n/a	n/a	**229**	< 7.43E+00	n/a	n/a
106	2.52E+02	9.77%	> 354%	**157**	< 7.43E+00	n/a	n/a	**230**	< 7.43E+00	n/a	n/a
107	2.16E+02	14.8%	> 290%	**158**	< 7.43E+00	n/a	n/a	**232**	6.81E+02	1.23%	> 14629%
108	3.26E+01	9.04%	> 487%	**159**	< 7.43E+00	n/a	n/a	**233**	1.93E+01	3.58%	246%
109	1.10E+02	15.8%	> 2269%	**160**	< 7.43E+00	n/a	n/a	**234**	< 7.43E+00	n/a	n/a
110	1.44E+01	19.6%	> 210%	**161**	< 7.43E+00	n/a	n/a	**235**	1.41E+02	3.71%	220%
111	< 7.43E+00	n/a	n/a	**162**	< 7.43E+00	n/a	n/a	**236**	4.14E+01	7.22%	231%
112	1.27E+01	18.7%	62.4%	**163**	< 7.43E+00	n/a	n/a	**237**	2.85E+01	6.85%	62.6%
113	< 7.43E+00	n/a	n/a	**164**	< 7.43E+00	n/a	n/a	**238**	2.83E+03	2.21%	652%
114	1.16E+01	36.1%	51.7%	**165**	< 7.43E+00	n/a	n/a	**239**	8.30E+00	0.275%	> 79.5%
116	1.39E+02	6.23%	29.9%	**166**	< 7.43E+00	n/a	n/a	**240**	< 7.43E+00	n/a	n/a
117	8.34E+01	11.9%	14.3%	**167**	< 7.43E+00	n/a	n/a	**241**	< 7.43E+00	n/a	n/a
118	2.36E+02	7.67%	10.2%	**168**	< 7.43E+00	n/a	n/a	**242**	< 7.43E+00	n/a	n/a
119	1.24E+02	5.62%	67.7%	**169**	< 7.43E+00	n/a	n/a	**243**	< 7.43E+00	n/a	n/a
120	3.22E+02	8.99%	10.5%	**170**	< 7.43E+00	n/a	n/a	**244**	< 7.43E+00	n/a	n/a
121	2.22E+01	84.3%	> 379%	**171**	< 7.43E+00	n/a	n/a	**245**	< 7.43E+00	n/a	n/a
122	8.51E+01	9.22%	11.5%	**172**	< 7.43E+00	n/a	n/a	**246**	< 7.43E+00	n/a	n/a
123	2.51E+01[b]	n/a	> 442%	**173**	< 7.43E+00	n/a	n/a	**247**	< 7.43E+00	n/a	n/a
124	1.30E+02	5.29%	7.39%	**174**	< 7.43E+00	n/a	n/a	**248**	< 1.49E+01	n/a	n/a
125	< 7.43E+00	n/a	n/a	**175**	< 7.43E+00	n/a	n/a	**249**	< 7.43E+00	n/a	n/a
126	3.97E+02	0.721%	-0.559%	**176**	< 7.43E+00	n/a	n/a	**250**	< 7.43E+00	n/a	n/a
128	< 7.43E+00	n/a	n/a	**177**	< 7.43E+00	n/a	n/a	**251**	< 7.43E+00	n/a	n/a
130	1.63E+01	23.9%	> 251%	**178**	< 7.43E+00	n/a	n/a				
133	6.09E+03	0.597%	-1.63%	**179**	< 7.43E+00	n/a	n/a				

*Shaded cells indicate masses where the difference between the filtrate and digested slurry is greater than 20% (ICP-MS method uncertainty). [a]The %RSD is based on the standard deviation of duplicate samples. The reported method uncertainty is 20% at two sigma. [b]Single result above the method detection limit. The duplicate sample had a reported concentration of < 7.01E+00 µg/L.

3.3 Tank 10H In-Tank Batch Contact Samples

Duplicate aliquots of the solutions generated from digestion of the CST contained in the teabags and the CST digestion standards, as well as the soak solutions, were submitted for replicate gamma spectroscopy analysis. Soak solutions were all 65 mL in volume. The individual results of these analyses, as well as the average and standard deviations of the replicates are shown in Table 3-14. The activity per gram is calculated based on the air-dried mass of CST that was used for the digestion.

Table 3-14. ^{137}Cs Activity from Gamma Counting for In-Tank Batch Contact Samples, Digestion Standards, and Soak Solutions

	Replicate 1	Replicate 2	Average	St. Dev.[a]	%RSD[b]
Teabag B3	5.68E+10 dpm/g	5.82E+10 dpm/g	5.75E+10 dpm/g	9.90E+08 dpm/g	1.72%
Teabag B4	6.19E+10 dpm/g	6.17E+10 dpm/g	6.18E+10 dpm/g	1.63E+08 dpm/g	0.263%
Teabag B5	7.22E+10 dpm/g	7.13E+10 dpm/g	7.18E+10 dpm/g	6.13E+08 dpm/g	0.855%
Teabag B6	8.30E+10 dpm/g	8.45E+10 dpm/g	8.38E+10 dpm/g	1.06E+09 dpm/g	1.27%
CST Standard B3	< 5.06E+07 dpm/g	< 5.62E+07 dpm/g	< 5.34E+07dpm/g	n/a	n/a
CST Standard B4	7.52E+07 dpm/g	6.28E+07 dpm/g	6.90E+07 dpm/g	8.77E+06 dpm/g	12.7%
Teabag B3 – 0.01 M NaOH soak	< 1.24E+06 dpm/mL	< 1.02E+06 dpm/mL	< 1.13E+06 dpm/mL	1.56E+05 dpm/mL	13.8%
Teabag B3 – DI Water soak	< 3.11E+05 dpm/mL	< 1.92E+05 dpm/mL	< 2.52E+05 dpm/mL	8.41E+04 dpm/mL	33.5%
Teabag B4 – 0.01 M NaOH soak	< 1.02E+06 dpm/mL	< 4.63E+05 dpm/mL	< 7.42E+05 dpm/mL	3.94E+05 dpm/mL	53.1%
Teabag B4 – DI Water soak	< 5.19E+05 dpm/mL	< 1.84E+05 dpm/mL	< 3.52E+05 dpm/mL	2.27E+05 dpm/mL	67.4%
Teabag B5 – 0.01 M NaOH soak	3.83E+05 dpm/mL	< 8.93E+05 dpm/mL	< 6.38E+05 dpm/mL	3.61E+05 dpm/mL	56.5%
Teabag B5 – DI Water soak	< 2.66E+05 dpm/mL	< 8.93E+05 dpm/mL	< 5.80E+05 dpm/mL	4.43E+05 dpm/mL	76.5%
Teabag B6 – 0.01 M NaOH soak	< 4.57E+05 dpm/mL	2.39E+05 dpm/mL	< 3.48E+05 dpm/mL	1.54E+05 dpm/mL	44.3%
Teabag B6 – DI Water soak	< 2.40E+05 dpm/mL	< 8.93E+05 dpm/mL	<5.67E+05 dpm/mL	4.62E+05 dpm/mL	81.5%

Units: ^{137}Cs dpm/g air-dried CST; ^{137}Cs dpm/mL of soak solution [a]The less than values for the soak solutions were treated as real values for purposes of calculating a standard deviation. [b]The %RSD is based on the standard deviation of the replicate samples. The reported method uncertainty is 5% at one sigma.

Two aliquots of the CST standard were digested alongside the CST from the teabags in the Shielded Cells, and solutions from these digestions were analyzed by gamma spectroscopy as well as ICP-MS. The main purpose of these standards is to confirm complete digestion of the CST; however, they also serve as a blank to detect contamination of the samples during handling and digestion in the Shielded Cells. As can be seen in Table 3-14, one standard had a ^{137}Cs activity below the method detection limit, while the other did have some detectible activity; however, it was approximately 3 orders of magnitude lower than what was observed on the teabag CST and therefore indicates no significant level of contamination that would have affected the results. The amount of ^{137}Cs found in the soak solutions used for rinsing the teabags was also below the detection limit in most cases. Treating the detection limit values as real values, the amount of ^{137}Cs in the combined 0.01 M NaOH and DI water solutions for each teabag amounted to less than 3% of the ^{137}Cs found on the CST. The ICP-MS analysis of the standards showed Ti, Nb, and Zr concentrations within the control limits established during the development of the standard.[9] The Ti, Nb, and Zr concentrations measured for teabags B3 and B4 were also within the standard control limits; however, Ti, Nb, and Zr concentrations measured for teabags B5 and B6 fell slightly below the standard control limits. This could be attributed to leaching of these elements from the CST during the 10-day soak in the tank.

The full suite of ICP-MS results for the in-tank batch contact samples and digestion standards are provided in Tables 3-16 through 3-19. The masses from 106 to 112 are due to the presence of mono oxides of Zr and Nb. The masses from 176-180 are from hafnium (Hf) which is a known contaminant of the Zr in the CST.

As described in Task 8 of the TTR,[13] the ^{137}Cs loading for a single in-tank batch contact teabag is calculated by adding the ^{137}Cs found in the two associated soak solutions (average plus 2 sigma uncertainty[c]) to the ^{137}Cs activity calculated from the average of replicate analyses of a single teabag sample (plus 2 sigma uncertainty[c]). Those results, along with the average and standard deviation of the two individual teabags, are provided in Table 3-15.

Table 3-15. Calculated ^{137}Cs Loadings on the Individual In-Tank Batch Contact Samples.[a]

	^{137}Cs Loading (dpm/g)	^{137}Cs Loading (Ci/kg$_{CST}$)
Teabag B3	6.07E+10	2.73E+01
Teabag B4	6.36E+10	2.87E+01
Average (B3/B4)	6.22E+10	2.80E+01
Standard Deviation	2.08E+09	9.39E-01
Teabag B5	7.47E+10	3.37E+01
Teabag B6	8.69E+10	3.92E+01
Average (B5/B6)	8.08E+10	3.64E+01
Standard Deviation	8.62E+09	3.88E+00

[a]Values include the 2 sigma uncertainties of the CST and soak solution measurements.

As stated above the ^{137}Cs loadings reported in Tables 3-14 and 3-15 are based on the air-dried mass of CST used for the digestions. To compare these results directly with the ZAM (Zheng, Anthony, Miller) modeling results, the loadings should be corrected for the true dry mass (i.e., mass remaining at 460 °C). For this batch of pretreated CST, the mass remaining at 460 °C was 81.07 wt %, which gives an F-factor of 0.8107.[9] The average ^{137}Cs loading from the duplicate teabags B3 and B4, corrected to the true dry mass, is 34.5 ± 1.16[d] Ci/kg$_{CST}$ and for duplicate teabags B5 and B6 the value is 44.9 ± 4.79[d] Ci/kg$_{CST}$.

[c] The 2-sigma uncertainty refers to 2 standard deviations of the replicate analyses.
[d] Standard deviation from Table 3-15 corrected to the true dry mass.

Table 3-16. ICP-MS Results for In-Tank Batch Contact Samples (Teabags B3 and B4)

m/z	Avg. Conc. (µg/g)	%RSD[a]	m/z	Avg. Conc. (µg/g)	%RSD[a]	m/z	Avg. Conc. (µg/g)	%RSD[a]
Ti	1.54E+05	7.84%	134	5.45E-01[c]	n/a	180	8.01E+02	9.13%
59	1.36E+00[b]	n/a	135	1.17E+02	5.20%	181	1.89E+02	8.47%
84	< 5.48E-01	n/a	136	7.22E-01[c]	n/a	182	6.42E-01[d]	n/a
85	1.46E+01	4.12%	137	2.61E+02	3.57%	183	< 5.48E-01	n/a
86	< 5.48E-01	n/a	138	6.31E+00	44.4%	184	6.40E-01	20.3%
87	3.22E+01	3.87%	139	1.57E+00	87.6%	185	< 5.48E-01	n/a
88	5.58E+00	25.6%	140	1.65E+01	13.7%	186	5.62E-01	9.73%
89	2.67E+00	15.0%	141	1.73E+00[c]	n/a	187	< 5.48E-01	n/a
Zr	9.84E+04	8.19%	142	3.06E+00	43.6%	188	< 5.48E-01	n/a
92	1.59E+04	7.75%	143	1.55E+00[c]	n/a	189	< 5.48E-01	n/a
Nb	1.26E+05	8.06%	144	1.88E+00[c]	n/a	191	< 5.48E-01	n/a
94	1.69E+04	8.17%	145	1.08E+00[c]	n/a	193	2.85E+00	10.7%
95	1.14E+00	63.5%	146	9.83E-01[c]	n/a	194	6.89E+00	8.41%
96	2.50E+03	7.35%	147	< 5.48E-01	n/a	195	3.95E+00	7.59%
97	1.34E+00[c]	n/a	148	6.07E-01[c]	n/a	196	9.10E+00	6.43%
98	1.40E+00[c]	n/a	149	< 5.48E-01	n/a	198	2.42E+01	37.6%
99	8.56E-01[c]	n/a	150	5.27E-01[c]	n/a	203	< 5.48E-01	n/a
100	1.27E+00[c]	n/a	151	< 5.48E-01	n/a	204	1.46E+01	35.2%
101	1.00E+00	49.0%	152	< 5.48E-01	n/a	205	< 5.48E-01	n/a
102	1.07E+00[c]	n/a	153	< 5.48E-01	n/a	206	4.87E+01	16.0%
103	1.04E+00	26.9%	154	< 5.48E-01	n/a	207	4.15E+01	16.4%
104	7.72E-01[c]	n/a	155	< 5.48E-01	n/a	208	1.01E+02	16.9%
105	5.42E-01[c]	n/a	156	< 5.48E-01	n/a	229	< 5.48E-01	n/a
106	6.71E+01	7.71%	157	< 5.48E-01	n/a	230	< 5.48E-01	n/a
107	2.33E+01	1.3%	158	< 5.48E-01	n/a	232	1.60E+01	132%
108	2.48E+01	6.22%	159	< 5.48E-01	n/a	233	8.98E-01[c]	n/a
109	1.48E+02	5.96%	160	< 5.48E-01	n/a	234	3.17E-01[c]	n/a
110	3.50E+01	7.10%	161	< 5.48E-01	n/a	235	5.25E+00	40.9%
111	2.76E+00	5.61%	162	< 5.48E-01	n/a	236	1.50E+00	43.5%
112	8.15E+00	5.07%	163	< 5.48E-01	n/a	237	1.24E+00	23.0%
113	5.34E-01[c]	n/a	164	< 5.48E-01	n/a	238	9.52E+01	81.0%
114	< 5.48E-01	n/a	165	< 5.48E-01	n/a	239	< 5.48E-01	n/a
116	1.37E+00[c]	n/a	166	< 5.48E-01	n/a	240	< 5.48E-01	n/a
117	< 5.48E-01	n/a	167	< 5.48E-01	n/a	241	< 5.48E-01	n/a
118	< 5.48E-01	n/a	168	< 5.48E-01	n/a	242	< 5.48E-01	n/a
119	1.91E+00	76.8%	169	< 5.48E-01	n/a	243	< 5.48E-01	n/a
120	7.30E-01	12.7%	170	< 5.48E-01	n/a	244	< 5.48E-01	n/a
121	1.50E+00	78.9%	171	< 5.48E-01	n/a	245	< 5.48E-01	n/a
122	< 5.48E-01	n/a	172	< 5.48E-01	n/a	246	< 5.48E-01	n/a
123	1.76E+00[d]	n/a	173	< 5.48E-01	n/a	247	< 5.48E-01	n/a
124	< 5.48E-01	n/a	174	3.39E+00	10.1%	248	< 6.13E-01	n/a
125	< 5.48E-01	n/a	175	< 5.48E-01	n/a	249	< 5.48E-01	n/a
126	7.69E-01	12.4%	176	1.14E+02	9.00%	250	< 5.48E-01	n/a
128	< 5.48E-01	n/a	177	4.13E+02	9.14%	251	< 5.48E-01	n/a
130	< 6.77E-01	n/a	178	6.18E+02	9.30%			
133	1.26E+03	6.42%	179	3.11E+02	10.1%			

[a]The %RSD is based on the standard deviation of duplicate samples. The reported method uncertainty is 20% at two sigma. [b]Single replicate above the detection limit (Teabag B3). Replicate value (Teabag B4) was < 1.01E+00 µg/g. [c]Single replicate above the detection limit (Teabag B3). Replicate value (Teabag B4) was < 5.81E-01 µg/g. [d]Single replicate above the detection limit (Teabag B4). Replicate value (Teabag B3) was < 5.15E-01 µg/g.

Table 3-17. ICP-MS Results for In-Tank Batch Contact Samples (Teabags B5 and B6)

m/z	Avg. Conc. (µg/g)	%RSD[a]	m/z	Avg. Conc. (µg/g)	%RSD[a]	m/z	Avg. Conc. (µg/g)	%RSD[a]
Ti	1.18E+05	1.95%	134	5.63E-01	6.46%	180	5.99E+02	3.80%
59	2.63E+00	10.4%	135	1.53E+02	10.3%	181	1.45E+02	1.03%
84	< 4.57E-01	n/a	136	8.55E-01	10.9%	182	8.32E-01	11.5%
85	1.22E+01	1.16%	137	3.58E+02	14.1%	183	4.28E-01[b]	n/a
86	4.29E-01[b]	n/a	138	7.95E+00	21.8%	184	9.47E-01	7.78%
87	2.71E+01	0.212%	139	4.62E-01[b]	n/a	185	< 4.57E-01	n/a
88	5.11E+00	4.38%	140	1.02E+01	12.1%	186	8.69E-01	9.79%
89	1.74E+00	0.604%	141	< 4.57E-01	n/a	187	< 4.57E-01	n/a
Zr	7.48E+04	3.04%	142	1.46E+00	14.4%	188	< 4.57E-01	n/a
92	1.20E+04	3.51%	143	< 4.57E-01	n/a	189	< 4.57E-01	n/a
Nb	9.63E+04	3.54%	144	< 4.57E-01	n/a	191	< 4.57E-01	n/a
94	1.28E+04	3.98%	145	< 4.57E-01	n/a	193	2.16E+00	6.52%
95	2.74E+00	83.0%	146	< 4.57E-01	n/a	194	5.19E+00	4.68%
96	1.91E+03	1.06%	147	< 4.57E-01	n/a	195	2.95E+00	7.23%
97	1.96E+00	73.5%	148	< 4.57E-01	n/a	196	6.73E+00	2.74%
98	3.38E+00	100%	149	< 4.57E-01	n/a	198	1.91E+01	1.21%
99	6.77E-01[b]	n/a	150	< 4.57E-01	n/a	203	< 4.57E-01	n/a
100	1.83E+00	77.8%	151	< 4.57E-01	n/a	204	1.39E+01	2.21%
101	< 6.51E-01	n/a	152	< 4.57E-01	n/a	205	< 4.57E-01	n/a
102	< 4.57E-01	n/a	153	< 4.57E-01	n/a	206	8.10E+01	5.66%
103	9.31E-01	2.54%	154	< 4.57E-01	n/a	207	6.93E+01	5.60%
104	< 4.57E-01	n/a	155	< 4.57E-01	n/a	208	1.71E+02	5.62%
105	< 4.57E-01	n/a	156	< 4.57E-01	n/a	229	< 4.57E-01	n/a
106	5.04E+01	3.35%	157	< 4.57E-01	n/a	230	< 4.57E-01	n/a
107	2.53E+01	39.0%	158	< 4.57E-01	n/a	232	8.64E-01	7.31%
108	1.86E+01	4.98%	159	< 4.57E-01	n/a	233	5.07E-01[b]	n/a
109	1.20E+02	10.2%	160	< 4.57E-01	n/a	234	< 4.57E-01	n/a
110	2.62E+01	3.34%	161	< 4.57E-01	n/a	235	3.59E+00	19.8%
111	2.05E+00	6.39%	162	< 4.57E-01	n/a	236	9.74E-01	20.6%
112	6.08E+00	1.91%	163	< 4.57E-01	n/a	237	1.37E+00	10.0%
113	< 4.57E-01	n/a	164	< 4.57E-01	n/a	238	4.49E+01	27.0%
114	< 4.57E-01	n/a	165	< 4.57E-01	n/a	239	4.38E-01[b]	n/a
116	< 4.57E-01	n/a	166	< 4.57E-01	n/a	240	< 4.57E-01	n/a
117	< 4.57E-01	n/a	167	< 4.57E-01	n/a	241	< 4.57E-01	n/a
118	5.00E-01[b]	n/a	168	< 4.57E-01	n/a	242	< 4.57E-01	n/a
119	9.57E-01	22.4%	169	< 4.57E-01	n/a	243	< 4.57E-01	n/a
120	6.34E-01	0.342%	170	< 4.57E-01	n/a	244	< 4.57E-01	n/a
121	< 4.57E-01	n/a	171	< 4.57E-01	n/a	245	< 4.57E-01	n/a
122	< 4.57E-01	n/a	172	< 4.57E-01	n/a	246	< 4.57E-01	n/a
123	< 4.57E-01	n/a	173	< 4.57E-01	n/a	247	< 4.57E-01	n/a
124	< 4.57E-01	n/a	174	2.52E+00	2.96%	248	< 4.57E-01	n/a
125	< 4.57E-01	n/a	175	< 4.57E-01	n/a	249	< 4.57E-01	n/a
126	6.15E-01	4.66%	176	8.52E+01	3.54%	250	< 4.57E-01	n/a
128	< 4.57E-01	n/a	177	3.07E+02	3.90%	251	< 4.57E-01	n/a
130	< 4.57E-01	n/a	178	4.60E+02	3.66%			
133	1.62E+03	10.9%	179	2.32E+02	4.46%			

[a]The %RSD is based on the standard deviation of duplicate samples. The reported method uncertainty is 20% at two sigma. [b]Single replicate above the detection limit (Teabag B6). Replicate value (Teabag B5) was < 5.26E-01 µg/g.

Table 3-18. ICP-MS Results for CST Digestion Standards

m/z	Avg. Conc. (µg/g)	%RSD[a]	m/z	Avg. Conc. (µg/g)	%RSD[a]	m/z	Avg. Conc. (µg/g)	%RSD[a]
Ti	1.48E+05	5.09%	134	< 4.88E-01	n/a	180	7.73E+02	6.45%
59	< 9.77E-01	n/a	135	< 4.88E-01	n/a	181	1.93E+02	1.34%
84	< 4.88E-01	n/a	136	< 4.88E-01	n/a	182	6.45E-01	20.5%
85	< 4.88E-01	n/a	137	6.27E-01[b]	n/a	183	< 4.88E-01	n/a
86	< 4.88E-01	n/a	138	2.48E+00	5.24%	184	7.52E-01	21.4%
87	< 4.88E-01	n/a	139	5.97E-01	4.33%	185	< 4.88E-01	n/a
88	2.99E+00	2.84%	140	1.33E+01	5.16%	186	6.76E-01	21.6%
89	2.04E+00	7.72%	141	< 4.88E-01	n/a	187	< 4.88E-01	n/a
Zr	9.46E+04	6.02%	142	1.94E+00	0.119%	188	< 4.88E-01	n/a
92	1.52E+04	5.88%	143	< 4.88E-01	n/a	189	< 4.88E-01	n/a
Nb	1.22E+05	4.91%	144	< 4.88E-01	n/a	191	< 4.88E-01	n/a
94	1.62E+04	5.46%	145	< 4.88E-01	n/a	193	2.89E+00	2.53%
95	< 4.88E-01	n/a	146	< 4.88E-01	n/a	194	6.74E+00	4.08%
96	2.42E+03	6.52%	147	< 4.88E-01	n/a	195	3.85E+00	5.95%
97	< 4.88E-01	n/a	148	< 4.88E-01	n/a	196	8.60E+00	4.96%
98	< 4.88E-01	n/a	149	< 4.88E-01	n/a	198	< 4.88E-01	n/a
99	< 4.88E-01	n/a	150	< 4.88E-01	n/a	203	< 4.88E-01	n/a
100	< 4.88E-01	n/a	151	< 4.88E-01	n/a	204	< 4.88E-01	n/a
101	< 4.88E-01	n/a	152	< 4.88E-01	n/a	205	< 4.88E-01	n/a
102	< 4.88E-01	n/a	153	< 4.88E-01	n/a	206	< 4.88E-01	n/a
103	< 4.88E-01	n/a	154	< 4.88E-01	n/a	207	< 4.88E-01	n/a
104	< 4.88E-01	n/a	155	< 4.88E-01	n/a	208	5.74E-01	10.2%
105	< 4.88E-01	n/a	156	< 4.88E-01	n/a	229	< 4.88E-01	n/a
106	6.45E+01	6.34%	157	< 4.88E-01	n/a	230	< 4.88E-01	n/a
107	2.12E+01	2.43%	158	< 4.88E-01	n/a	232	9.42E-01	5.29%
108	2.38E+01	4.78%	159	< 4.88E-01	n/a	233	< 4.88E-01	n/a
109	1.43E+02	4.30%	160	< 4.88E-01	n/a	234	< 4.88E-01	n/a
110	3.37E+01	5.59%	161	< 4.88E-01	n/a	235	< 4.88E-01	n/a
111	2.60E+00	10.7%	162	< 4.88E-01	n/a	236	< 4.88E-01	n/a
112	7.80E+00	4.39%	163	< 4.88E-01	n/a	237	< 4.88E-01	n/a
113	< 4.88E-01	n/a	164	< 4.88E-01	n/a	238	6.85E-01[b]	n/a
114	< 4.88E-01	n/a	165	< 4.88E-01	n/a	239	< 4.88E-01	n/a
116	< 4.88E-01	n/a	166	< 4.88E-01	n/a	240	< 4.88E-01	n/a
117	< 4.88E-01	n/a	167	< 4.88E-01	n/a	241	< 4.88E-01	n/a
118	< 4.88E-01	n/a	168	< 4.88E-01	n/a	242	< 4.88E-01	n/a
119	< 4.88E-01	n/a	169	< 4.88E-01	n/a	243	< 4.88E-01	n/a
120	< 4.88E-01	n/a	170	< 4.88E-01	n/a	244	< 4.88E-01	n/a
121	< 6.07E-01	n/a	171	< 4.88E-01	n/a	245	< 4.88E-01	n/a
122	< 4.88E-01	n/a	172	< 4.88E-01	n/a	246	< 4.88E-01	n/a
123	< 6.07E-01	n/a	173	< 4.88E-01	n/a	247	< 4.88E-01	n/a
124	< 4.88E-01	n/a	174	3.34E+00	6.19%	248	< 4.88E-01	n/a
125	< 4.88E-01	n/a	175	< 4.88E-01	n/a	249	< 4.88E-01	n/a
126	< 4.88E-01	n/a	176	1.10E+02	6.58%	250	< 4.88E-01	n/a
128	< 4.88E-01	n/a	177	3.98E+02	6.35%	251	< 4.88E-01	n/a
130	< 4.88E-01	n/a	178	5.90E+02	6.45%			
133	1.56E+00[b]	n/a	179	2.95E+02	7.12%			

[a]The %RSD is based on the standard deviation of duplicate samples. The reported method uncertainty is 20% at two sigma. [b]Single replicate above the detection limit (Standard B4). Replicate value (Standard B3) was < 4.72E-01 µg/g.

Loading of several other elements was observed on the teabag CST based on the ICP-MS and ICP-ES data. A summary of loading of other elements on the CST is provided in Table 3-19 in order of decreasing loading. A number of these elements are also present in the standard samples, indicating they are trace components of the as-manufactured and pretreated CST. Therefore, concentrations in both the teabag CST and standard CST are shown. The full ICP-ES results for the teabag samples and standards are provided in Table 3-20.

Table 3-19. Comparison of Cs Loading With That of Other Elements on the CST.[a]

Element	Avg. Amount in Teabags B3/B4 (mmol/g_{CST})	Avg. Amount in Teabags B5/B6 (mmol/g_{CST})	Avg. Amount in Standards (mmol/g_{CST})	Net Loading (Teabags B3/B4 -standard) (mmol/g_{CST})	Net Loading (Teabags B5/B6 -standard) (mmol/g_{CST})
Na	4.75E+00	4.57E+00	3.19E+00	1.56E+00	1.38E+00
Fe	2.47E-02[b]	3.48E-02	3.73E-03	2.09E-02	3.11E-02
Cs	**1.46E-02**	**1.79E-02**	**1.64E-05**	**1.45E-02**	**1.79E-02**
Al	1.84E-01	1.86E-01	1.71E-01	1.32E-02	1.43E-02
Ca	1.29E-02	1.49E-02	< 6.28E-03	> 6.67E-03	> 8.63E-03
Cr	< 6.91E-04	3.75E-03[c]	< 6.16E-04	n/a	> 3.13E-03
Pb	9.39E-04	1.57E-03	5.29E-06	9.33E-04	1.57E-03
Rb	5.47E-04	4.60E-04	< 1.14E-05	> 5.36E-04	> 4.48E-04
U	4.33E-04[d]	2.10E-04[e]	2.88E-06[f]	4.30E-04	2.07E-04
Sr	7.71E-05	7.07E-05	4.14E-05	3.58E-05	2.93E-05
Co	2.30E-05	4.46E-05	< 1.66E-05	> 6.45E-06	> 2.81E-05
Y	3.00E-05	1.96E-05	2.29E-05	7.06E-06	-3.32E-06
^{237}Np	5.24E-06	5.78E-06	< 2.06E-06	> 3.18E-06	> 3.72E-06

[a]Values have not been corrected for the F-factor. [b]Large discrepancy between the two teabags (97.7 %RSD), Teabag B3 had an Fe loading of 2330 µg/g and Teabag B4 had an Fe loading of 426 µg/g. [c]Single teabag above the method detection limit (Teabag B6). Teabag B5 had a reported Cr loading of < 34.5 µg/g. [d]Sum of isotopes 233, 234, 235, 236, and 238. [e]Sum of isotopes 233, 235, 236, and 238. Isotope 234 was below the detection limit. [f]Isotope 238 only, all others were below the detection limit in the standard samples.

Table 3-20. ICP-ES Results for the In-Tank Batch Contact Samples and Associated Digestion Standards

Element	Avg. Conc. In Teabags B3/B4 (µg/g)	%RSD[a]	Avg. Conc. In Teabags B5/B6 (µg/g)	%RSD[a]	Avg. Conc. In Standard Samples (µg/g)	%RSD[a]
Ag	< 436	n/a	< 364	n/a	< 389	n/a
Al	4980	1.88%	5000	2.07%	4620	21.4%
Ba	< 244	n/a	< 204	n/a	< 218	n/a
Be	< 10.1	n/a	< 8.42	n/a	< 8.99	n/a
Ca	519	36.6%	598	12.9%	< 252	n/a
Cd	< 5.05	n/a	< 4.2	n/a	< 4.5	n/a
Ce	< 240	n/a	< 200	n/a	< 214	n/a
Co	< 317	n/a	< 265	n/a	< 283	n/a
Cr	< 36	n/a	195[b]	n/a	< 32	n/a
Cu	< 725	n/a	< 605	n/a	< 646	n/a
Fe	1380	97.7%	1950	27.9%	209	17.9%
Gd	< 735	n/a	< 612	n/a	< 655	n/a
K	< 1310	n/a	< 1090	n/a	< 1170	n/a
La	< 8.83	n/a	< 7.36	n/a	< 7.87	n/a
Li	< 365	n/a	< 304	n/a	< 325	n/a
Mg	101	1.45%	92.1	3.39%	119	9.51%
Mn	< 177	n/a	< 147	n/a	< 158	n/a
Mo	< 35	n/a	< 29.2	n/a	< 31.2	n/a
Na	109000	17.8%	105000	0.113%	73300	2.19%
Nb	116000	7.33%	89600	1.85%	113000	5.07%
Ni	< 139	n/a	< 116	n/a	< 123	n/a
P	< 141	n/a	< 118	n/a	< 126	n/a
Pb	< 443	n/a	< 368	n/a	< 394	n/a
S	871[c]	n/a	849	17.3%	< 144	n/a
Sb	< 4730	n/a	< 3980	n/a	< 4240	n/a
Sn	< 620	n/a	< 517	n/a	< 552	n/a
Sr	< 8.19	n/a	< 6.84	n/a	< 7.3	n/a
Th	< 1410	n/a	< 1180	n/a	< 1260	n/a
Ti	141000	7.26%	110000	2.37%	136000	4.77%
U	< 895	n/a	< 746	n/a	< 798	n/a
V	< 101	n/a	< 83.8	n/a	< 89.6	n/a
Zn	< 104	n/a	< 86.8	n/a	< 92.8	n/a
Zr	95400	8.51%	74100	2.83%	92600	5.48%

[a]The %RSD is based on the standard deviation of duplicate samples. The reported analytical method uncertainties (at two sigma) are 10%. [b]Single teabag above the method detection limit (Teabag B6). Teabag B5 had a reported Cr loading of < 34.5 µg/g. [c]Single teabag above the method detection limit (Teabag B3). Teabag B4 had a reported S loading of < 172 µg/g.

A summary of other radionuclide data for the in-tank batch contact samples as well as the CST digestion standards is provided in Table 3-21. The gamma emitting isotopes were measured by gamma spectroscopy after Cs removal, the ^{90}Sr and Pu isotopes were measured after separation, and the total alpha and beta were measured by LSC both with and without Cs removal. Based on the cesium results it is assumed that radionuclide losses to the wash solutions are small relative to the amounts recovered from the teabags.

Table 3-21. Other Radionuclide Activities in the In-Tank Batch Contact Samples and CST Digestion Standards (Not Corrected for the F-Factor)

Isotope	Avg. Activity in Teabag B3/B4 CST (dpm/g$_{CST}$)	%RSD[a] (Avg. Method Unc.)	Avg. Activity in Teabag B5/B6 CST (dpm/g$_{CST}$)	%RSD[a] (Avg. Method Unc.)	Avg. Activity in Standard CST (dpm/g$_{CST}$)	%RSD[a] (Avg. Method Unc.)
^{60}Co	< 4.02E+03	n/a (MDA)	< 3.35E+03	n/a (MDA)	< 1.73E+03	n/a (MDA)
^{90}Sr	6.48E+07	94.2% (33.6%)	5.77E+07	15.0% (35.4%)	< 1.52E+05	n/a (MDA/ Upper Limit)
^{106}Ru	< 3.52E+04	n/a (MDA)	< 2.75E+04	n/a (MDA)	< 1.02E+04	n/a (MDA)
^{125}Sb	< 2.33E+04	n/a (MDA)	< 1.92E+04	n/a (MDA)	< 5.57E+03	n/a (MDA)
^{126}Sb	< 6.47E+03	n/a (MDA)	< 5.24E+03	n/a (MDA)	< 1.90E+03	n/a (MDA)
^{126}Sn	< 1.51E+04	n/a (MDA)	< 1.25E+04	n/a (MDA)	< 3.23E+03	n/a (MDA)
^{135}Cs	4.13E+05	6.28% (5.17%)	5.42E+05	8.41% (5.06%)	5.56E+02[b]	n/a (34.7%)
^{144}Ce	< 4.50E+04	n/a (MDA)	< 3.73E+04	n/a (MDA)	< 1.26E+04	n/a (MDA)
^{154}Eu	2.25E+04[c]	n/a (12.0%)	< 1.02E+04	n/a (MDA)	< 3.23E+03	n/a (MDA)
^{238}Pu	4.81E+06	42.2% (7.27%)	6.13E+06	22.4% (8.41%)	< 2.80E+03	n/a (MDA)
$^{239/240}$Pu	7.31E+04	53.9% (14.0%)	9.50E+04	25.3% (10.9%)	3.36E+03[d]	n/a (58.3%)
^{241}Pu	6.56E+05	14.7% (16.7%)	8.36E+05	68.3% (16.7%)	< 4.51E+04	n/a (MDA)
^{241}Am	7.09E+04[e]	n/a (12.8%)	< 1.63E+04	n/a (MDA)	< 3.12E+03	n/a (MDA)
Alpha Count[f]	< 3.82E+08	n/a (Upper Limit)	< 5.11E+08	n/a (Upper Limit)	< 3.67E+08	n/a (MDA)
Beta Count[f]	7.59E+10	5.55% (10.0%)	9.97E+10	10.3% (10.0%)	< 1.75E+08	n/a (MDA)
Alpha Count[g]	< 4.69E+06	n/a (Upper Limit)	< 5.06E+06	n/a (Upper Limit)	< 1.25E+04	n/a (MDA)
Beta Count[g]	1.82E+08	81.1% (10.0%)	1.34E+08	15.0% (10.0%)	3.33E+05	67.6% (36.0%)

[a]The %RSD is based on the standard deviation of duplicate samples. [b]Single standard above the method detection limit (Standard B4). Standard B3 was < 2.89E+02 dpm/g. [c]Single teabag above the method detection limit (Teabag B3). Teabag B4 was < 9.53E+03 dpm/g. [d]Single standard above the method detection limit (Standard B4). Standard B3 was < 1.50E+03 dpm/g. [e]Single teabag above the method detection limit (Teabag B3). Teabag B4 was < 1.46E+04 dpm/g. [f]From LSC without Cs removal. [g]From LSC after Cs removal.

In addition to analyzing the digested CST, the rinse solutions generated from rinsing the teabags prior to disassembly were analyzed. As reported above, the amount of ^{137}Cs found in the soak solutions was very low. Adding the amount of ^{137}Cs in the combined 0.01 M NaOH and DI water solutions for each teabag increased the ^{137}Cs on the CST in teabags less than 3%. Duplicate aliquots of each soak solution were also analyzed by ICP-ES and those results are provided in Table 3-22. As can be seen in the table, the soak solutions showed very low concentrations of a few elements, with a composition that is consistent with residual salt solution being retained in the teabags. The average measured sodium concentration of the 0.01 M NaOH rinses from Teabags B3 and B4 was 0.102 M, which is equivalent to ~ 0.9 mL of the Tank 10H supernate being diluted into the 65 mL of 0.01 M NaOH rinse solution. For Teabags B5 and B6 the

average sodium concentration of the 0.01 M NaOH rinses was 0.093 M, which is equivalent to ~ 0.8 mL of the Tank 10H supernate being diluted into the rinse solution. The DI water rinses contained an average of 53 mg/L and 52 mg/L of Na for Teabags B3/B4 and Teabags B5/B6, respectively. This is equivalent to ~ 1.5 mL or ~ 1.6 mL, respectively, of the first rinses (0.01 M NaOH) being carried over into the water rinses.

Table 3-22. Full ICP-ES Results for the Soak Solutions

Element	Avg. Conc. in B3/B4 0.01 M NaOH rinse solutions (mg/L)	%RSD[a]	Avg. Conc. in B3/B4 DI water rinse solutions (mg/L)	%RSD[a]	Avg. Conc. in B5/B6 0.01 M NaOH rinse solutions (mg/L)	%RSD[a]	Avg. Conc. in B5/B6 DI water rinse solutions (mg/L)	%RSD[a]
Ag	< 0.015	n/a	< 0.015	n/a	< 0.015	n/a	< 0.015	n/a
Al	39.0	1.64%	1.002	8.21%	35.1	16.8%	1.029	35.6%
B	< 0.062	n/a	< 0.062	n/a	< 0.062	n/a	< 0.062	n/a
Ba	< 0.013	n/a	< 0.013	n/a	< 0.013	n/a	< 0.013	n/a
Be	< 0.00258	n/a	< 0.00258	n/a	< 0.00258	n/a	< 0.00258	n/a
Ca	0.633[b]	4.02%	0.159[b]	2.23%	< 0.081	n/a	< 0.081	n/a
Cd	< 0.00337	n/a	< 0.00337	n/a	< 0.00337	n/a	< 0.00337	n/a
Ce	< 0.305	n/a	< 0.305	n/a	< 0.305	n/a	< 0.305	n/a
Co	< 0.0136	n/a	< 0.0136	n/a	< 0.0136	n/a	< 0.0136	n/a
Cr	0.400	14.5%	< 0.016	n/a	0.308	16.8%	< 0.016	n/a
Cu	< 0.025	n/a	< 0.025	n/a	< 0.025	n/a	< 0.025	n/a
Fe	0.321[b]	6.17%	< 0.057	n/a	< 0.057	n/a	< 0.057	n/a
Gd	< 0.0112	n/a	< 0.0112	n/a	< 0.0112	n/a	< 0.0112	n/a
K	< 4.58	n/a	< 4.58	n/a	< 4.58	n/a	< 4.58	n/a
La	< 0.00685	n/a	< 0.00685	n/a	< 0.00685	n/a	< 0.00685	n/a
Li	< 0.665	n/a	< 0.665	n/a	< 0.665	n/a	< 0.665	n/a
Mg	< 0.012	n/a	< 0.012	n/a	< 0.012	n/a	< 0.012	n/a
Mn	0.511[b]	1.52%	< 0.047	n/a	< 0.047	n/a	< 0.047	n/a
Mo	0.195	6.25%	< 0.0205	n/a	0.167	16.8%	< 0.0205	n/a
Na	2343	0.640%	52.8	6.84%	2138	14.2%	52.3	6.02%
Nb	< 0.0575	n/a	< 0.0575	n/a	< 0.0575	n/a	< 0.0575	n/a
Ni	< 0.091	n/a	< 0.091	n/a	< 0.091	n/a	< 0.091	n/a
P	1.32	10.7%	< 0.061	n/a	1.09	19.6%	< 0.061	n/a
Pb	< 0.140	n/a	< 0.140	n/a	< 0.140	n/a	< 0.140	n/a
S	45.0	5.77%	0.956	14.4%	40.0	19.8%	0.932	6.74%
Sb	< 0.0631	n/a	< 0.0631	n/a	< 0.0631	n/a	< 0.0631	n/a
Si	< 0.149	n/a	< 0.149	n/a	< 0.149	n/a	< 0.149	n/a
Sn	< 0.312	n/a	< 0.312	n/a	< 0.312	n/a	< 0.312	n/a
Sr	< 0.009	n/a	< 0.009	n/a	< 0.009	n/a	< 0.009	n/a
Th	< 0.346	n/a	< 0.346	n/a	< 0.346	n/a	< 0.346	n/a
Ti	< 0.0619	n/a	< 0.0619	n/a	< 0.0619	n/a	< 0.0619	n/a
U	< 0.239	n/a	< 0.239	n/a	< 0.239	n/a	< 0.239	n/a
V	< 0.106	n/a	< 0.106	n/a	< 0.106	n/a	< 0.106	n/a
Zn	< 0.00615	n/a	< 0.00615	n/a	< 0.00615	n/a	< 0.00615	n/a
Zr	< 0.016	n/a	< 0.016	n/a	< 0.016	n/a	< 0.016	n/a

[a]The %RSD is based on the standard deviation of four samples (duplicates for each teabag). The reported analytical method uncertainty (at two sigma) is 10%. [b]Average and %RSD of duplicate samples from one soak solution (Teabag B3) as the other was below the detection limit.

3.4 ZAM Modeling Results

The measured compositions of the three Tank 10H Batch 1 qualification samples (HTF-10-21-125, HTF-10-21-126, and HTF-10-21-127) were used as input for the ZAM modeling calculations. The ionic charges of the measured concentrations are not balanced. For each sample the total positive charge was less than the total negative. In the past, the total charge of anions is usually less than the total charge of cations; and therefore, the common practice has been to increase the Cl^- concentration to achieve the charge balance, because the change in chloride concentration has a minimal impact on cesium loading. Since that is not possible for this case, two options were considered for balancing the charges in the Batch 1 solutions.

1. Adjustment of anions: All anion concentrations are equally decreased by multiplying by a factor to have a complete charge balance. This is shown in Column 3 of Tables 3-23, 3-24, and 3-25.
2. Adjustment of Na^+: Increasing the Na^+ concentration to match the total anion concentration. This is shown in Column 4 of Tables 3-23, 3-24, and 3-25.

As seen in Tables 3-23, 3-24, and 3-25 the second option (i.e., Na^+ adjustment) provides a more accurate density in comparison with the measured densities in each case. Therefore, Option 2 (Na^+ adjustment) was selected as the adjusted composition for modeling purposes. It should be noted, however, that the Na^+ concentration used as input has the largest effect on the Cs loading predicted by the model. Each 1% increase in Na^+ concentration correlates to a 2.1% decrease in the predicted Cs loading.[11]

Table 3-23. TCCR 1A Batch 1 Sample HTF-10-21-125 Concentrations at 31 ºC

Component	HTF-10-21-125 Measured Concentrations (M)	HTF-10-21-125 Anion Adjusted Concentrations (M)	HTF-10-21-125 Na^+ Adjusted Concentrations (M)
Na^+	6.86	6.86	7.61517
K^+	$< 8.06\times10^{-3}$	0	0
Cs^+	6.20×10^{-5}	6.20×10^{-5}	6.20×10^{-5}
Rb^+	2.85×10^{-5}	2.85×10^{-5}	2.85×10^{-5}
Total Sr	4.50×10^{-7}	4.50×10^{-7}	4.50×10^{-7}
Pb^{2+}	5.62×10^{-6}	5.62×10^{-6}	5.62×10^{-6}
OH^-	0.367	0.331	0.367
NO_3^-	4.60	4.144	4.60
NO_2^-	0.603	0.543	0.603
$Al(OH)_4^-$	0.101	0.091	0.101
CO_3^{2-}	0.836	0.753	0.836
SO_4^{2-}	0.131	0.118	0.131
Cl^-	$< 1.09\times10^{-2}$	0	0
F^-	$< 2.03\times10^{-2}$	0	0
PO_4^{3-}	$< 4.06\times10^{-3}$	0	0
$C_2O_4^{2-}$	4.65×10^{-3}	4.19×10^{-3}	4.65×10^{-3}
CrO_4^{2-}	4.86×10^{-4}	4.38×10^{-4}	4.86×10^{-4}
Measured Density (g/cm³) at 17 °C	1.361		
OLI Density (g/cm³) at 17 °C		1.322	1.352
OLI Density (g/cm³) at 31 °C		1.313	1.343

Table 3-24. TCCR 1A Batch 1 Sample HTF-10-21-126 Concentrations at 31 ºC

Component	HTF-10-21-126 Measured Concentrations (M)	HTF-10-21-126 Anion Adjusted Concentrations (M)	HTF-10-21-126 Na^+ Adjusted Concentrations (M)
Na^+	5.46	5.46	5.7789
K^+	$< 7.82x10^{-3}$	0	0
Cs^+	$4.44x10^{-5}$	$4.44x10^{-5}$	$4.44x10^{-5}$
Rb^+	$2.08x10^{-5}$	$2.08x10^{-5}$	$2.08x10^{-5}$
Total Sr	$3.36x10^{-7}$	$3.36x10^{-7}$	$3.36x10^{-7}$
Pb^{2+}	$4.35x10^{-6}$	$4.35x10^{-6}$	$4.35x10^{-6}$
OH^-	0.562	0.531	0.562
NO_3^-	3.25	3.071	3.25
NO_2^-	0.423	0.400	0.423
$Al(OH)_4^-$	$7.91x10^{-2}$	$7.47x10^{-2}$	$7.91x10^{-2}$
CO_3^{2-}	0.653	0.075	0.653
SO_4^{2-}	$7.91x10^{-2}$	0.118	$7.91x10^{-2}$
Cl^-	$< 1.25x10^{-2}$	0	0
F^-	$< 2.33x10^{-2}$	0	0
PO_4^{3-}	$< 4.65x10^{-3}$	0	0
$C_2O_4^{2-}$	$< 5.02x10^{-3}$	0	0
CrO_4^{2-}	$3.38x10^{-4}$	$3.19 x10^{-4}$	$3.38x10^{-4}$
Measured Density (g/cm^3) at 17 °C	1.302		
OLI Density (g/cm^3) at 17 °C		1.260	1.273
OLI Density (g/cm^3) at 31 °C		1.253	1.266

Table 3-25. TCCR 1A Batch 1 Sample HTF-10-21-127 Measured Concentrations at 31 ºC

Component	Tank 10H TCCR 1A Batch 1 Measured Concentrations (M)	Tank 10H TCCR 1A Batch 1 Anion Adjusted Concentrations (M)	Tank 10H TCCR 1A Batch 1 Na^+ Adjusted Concentrations (M)
Na^+	7.0	7.0	7.7678
K^+	$< 8.13x10^{-3}$	0	0
Cs^+	$6.49x10^{-5}$	$6.49x10^{-5}$	$6.49x10^{-5}$
Rb^+	$2.88\ x10^{-5}$	$2.88\ x10^{-5}$	$2.88\ x10^{-5}$
Total Sr	$3.48x10^{-7}$	$3.48x10^{-7}$	$3.48x10^{-7}$
Pb^{2+}	$3.31x10^{-6}$	$3.31x10^{-6}$	$3.31x10^{-6}$
OH^-	0.361	0.325	0.361
NO_3^-	4.63	4.172	4.63
NO_2^-	0.653	0.588	0.653
$Al(OH)_4^-$	0.113	0.102	0.113
CO_3^{2-}	0.851	0.767	0.851
SO_4^{2-}	0.154	0.139	0.154
Cl^-	$< 1.30x10^{-2}$	0	0
F^-	$< 2.44x10^{-2}$	0	0
PO_4^{3-}	$< 4.87x10^{-3}$	0	0
$C_2O_4^{2-}$	$< 5.26x10^{-3}$	0	0
CrO_4^{2-}	$4.51x10^{-4}$	4.06E-04	$4.51x10^{-4}$
Measured Density (g/cm^3) at 17 °C	1.384		
OLI Density (g/cm^3) at 17 °C		1.328	1.359
OLI Density (g/cm^3) at 31 °C		1.319	1.349

The CST isotherm was determined by use of the Freundlich/Langmuir Hybrid model to fit the ZAM data. The isotherm parameters are listed in Table 3-26. With the parameters listed, the expression reduces to a Langmuir isotherm.

Freundlich/Langmuir Hybrid isotherm model:

$$q = \frac{\eta_{CF} C_T \rho_{Bed} C_p}{\beta + C_p}$$

q: Cesium loading on CST (mol_{Cs}/L_{Bed})
C_p: Liquid-phase cesium concentration (mol_{Cs}/L)
C_T: Total cesium ion-exchange capacity of CST ($mmol_{Cs}/g_{CST,powder}$)
η_{CF}: Dilution/Correction factor ($g_{CST,powder}/g_{CST,eng}$)
ρ_{Bed}: Bed density ($g_{CST,eng}/mL_{Bed}$)
β: Langmuir isotherm parameter

Table 3-26. Isotherm Parameters

Case	Adjustment	T (°C)	η_{CF}	C_T ($mmol_{Cs}/g_{CST}$)	$\rho_{Bed,dry}$[a] (g_{CST}/ml_{Bed})	β
HTF-10-21-125	Anions	31	1.0	0.58	0.999	5.4408E-04
	Na^+	31	1.0	0.58	0.999	7.1008E-04
HTF-10-21-126	Anions	31	1.0	0.58	0.999	3.0235E-04
	Na^+	31	1.0	0.58	0.999	3.3682E-04
HTF-10-21-127	Anions	31	1.0	0.58	0.999	5.6316E-04
	Na^+	31	1.0	0.58	0.999	7.3649E-04

[a]Dry bed density calculated from bed density (1.232 g/mL) and F-factor (0.8107).[9]

The maximum cesium loading for each composition was calculated by the method of phase ratio variation. Cesium loadings at 31 °C are given in Table 3-27 and are on a true dry mass basis (i.e., accounting for the F-factor). The ZAM loading value for samples HTF-10-21-125 and HTF-10-21-127 (engineered forms) are ~1.4x larger than the measured teabag (B5/B6) result. The ZAM loading for sample HTF-10-21-126 (engineered form) is ~2x larger than the measured teabag (B5/B6) result. In general, these ratios are lower compared to what was observed for prior TCCR in-tank batch contact testing where the ZAM results were typically >2x higher than the measured values.[16,17,18] The measured teabag loading is likely slightly lower than the maximum equilibrium loading achievable as previous laboratory testing of the teabag devices indicated that the loading obtained in an unagitated experiment is approximately 6% lower than obtained for a continuously stirred experiment.[19]

Table 3-27. Maximum Cesium Loading at 31 °C

Case	q (Powder Form)[a]		q (Engineered Form)[b]		Teabags B3/B4		Teabags B5/B6	
	$mmol_{Cs}/g_{CST}$	Ci/kg_{CST}	$mmol_{Cs}/g_{CST}$	Ci/kg_{CST}	$mmol_{Cs}/g_{CST}$	Ci/kg_{CST}	$mmol_{Cs}/g_{CST}$	Ci/kg_{CST}
HTF-10-21-125	0.047	90.9	0.032	61.8	0.0187	34.5	0.0230	44.9
HTF-10-21-126	0.068	132	0.046	89.8				
HTF-10-21-127	0.047	91.9	0.032	62.5				

[a]Calculated from ZAM. [b]Applied dilution factor η_{df} of 0.68 to ZAM values.

Cesium loading and isotherms for both the anion adjusted and Na^+ adjusted compositions for the three samples are shown in Figures 3-3 through 3-5, along with the teabag (B5/B6) result. Dilution factors (η_{df})

of 0.34 to 0.494 were required to match the experimental data with the calculated isotherm for the Na^+ adjusted compositions. The lowest dilution factor (i.e., closest to the experimental data) was for the HTF-10-21-125 sample. The dilution factors required to match the B3/B4 teabag results ranged from 0.28 to 0.40. A comparison of the isotherms for the three samples is shown in Figure 3-6. Samples HTF-10-21-125 and HTF-10-21-127 show practically identical loadings, while HTF-10-21-126 displays much higher loading.

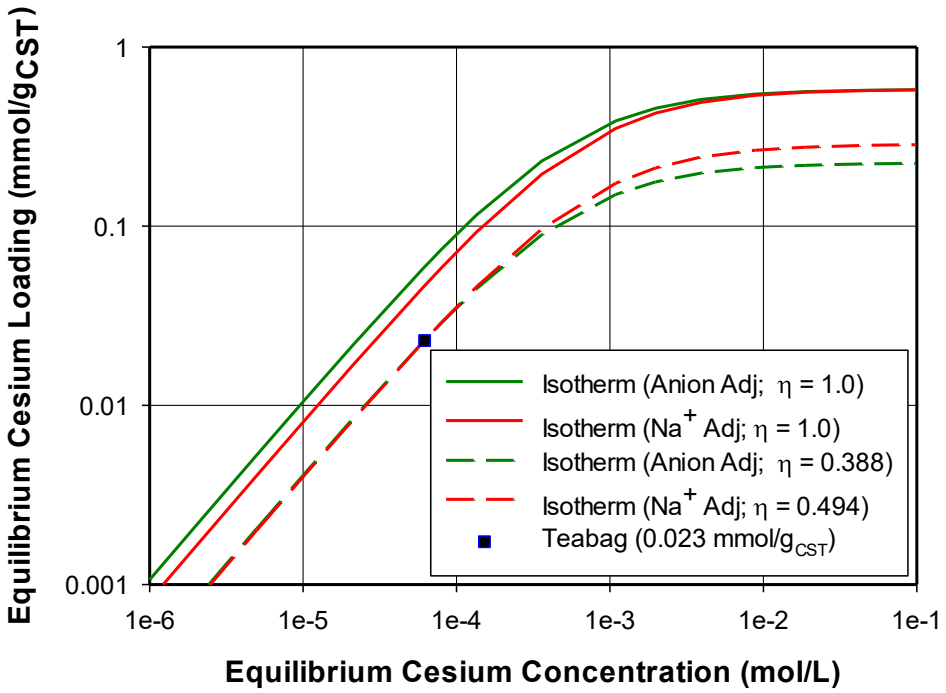

Figure 3-3. TCCR 1A Batch 1 Isotherms at 31 °C (Sample HTF-10-21-125)

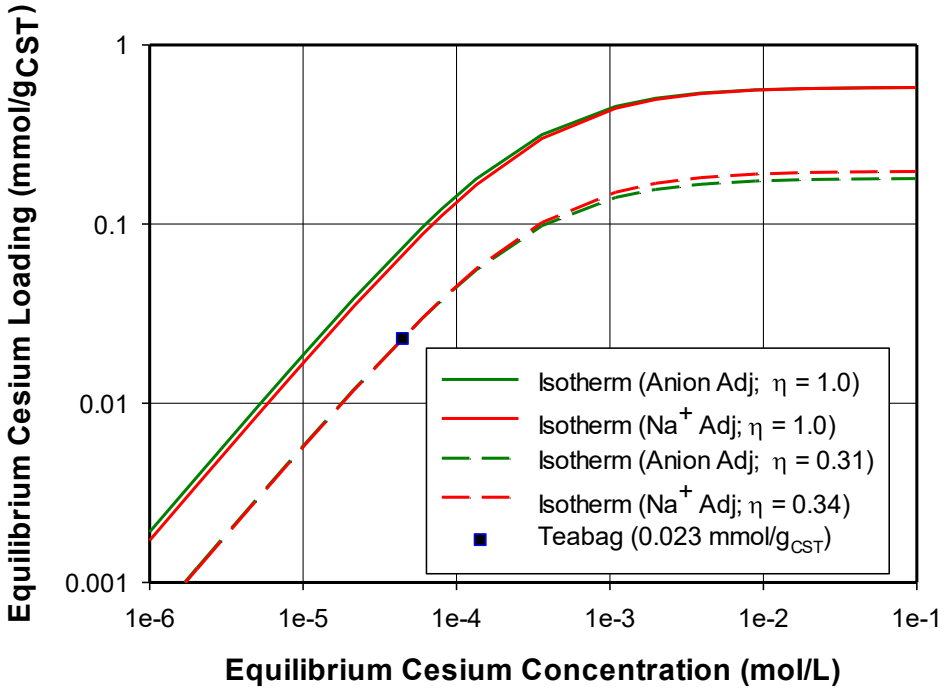

Figure 3-4. TCCR 1A Batch 1 Isotherms at 31 °C (Sample HTF-10-21-126)

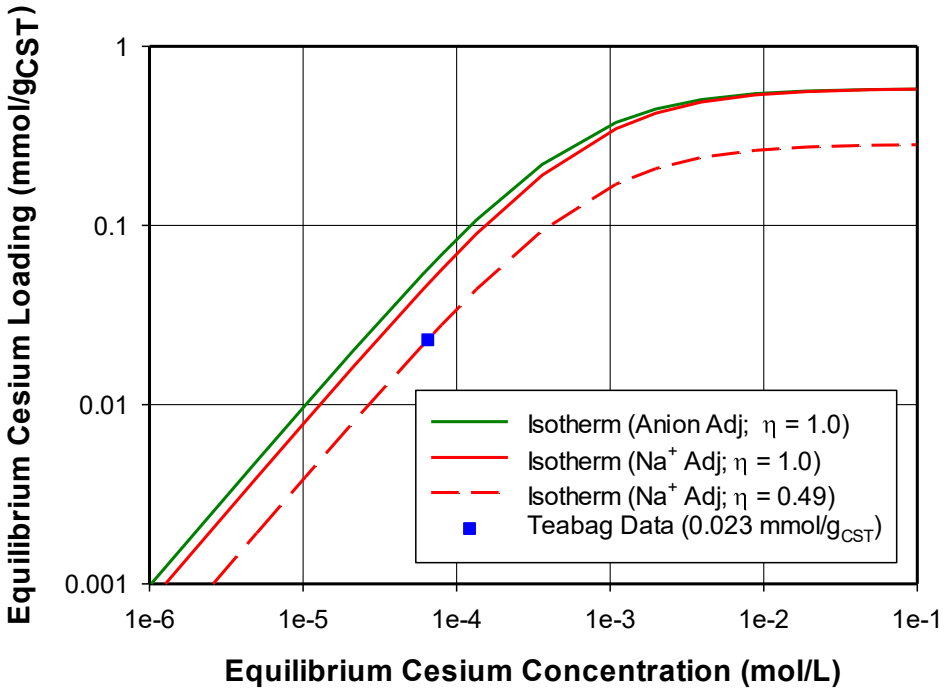

Figure 3-5. TCCR 1A Batch 1 Isotherms at 31 °C (Sample HTF-10-21-127)

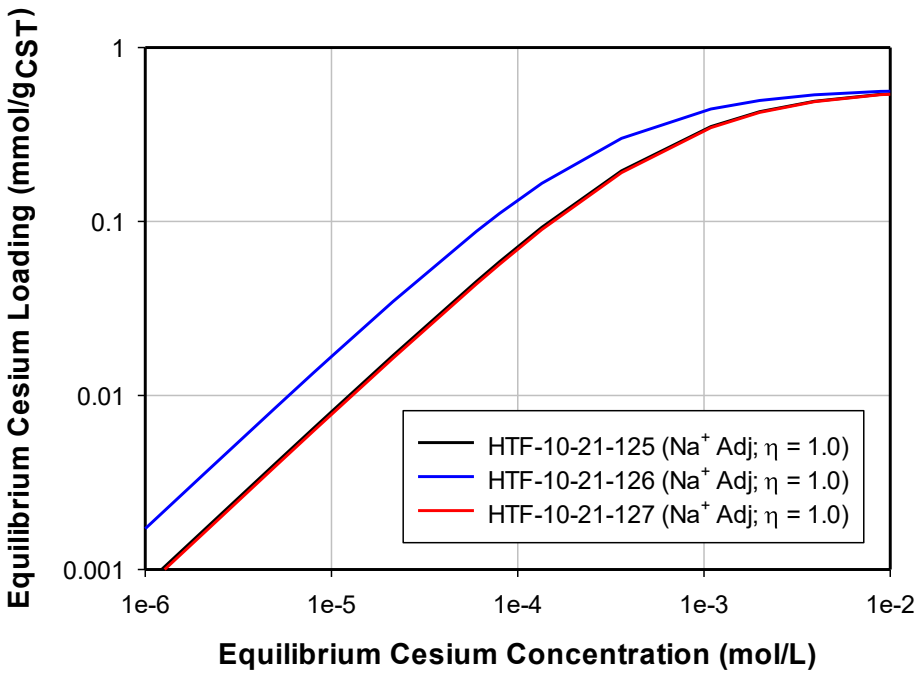

Figure 3-6. Cesium Loading Comparison for Three Samples

4.0 Conclusions

SRNL received and characterized several sets of samples collected from Tank 10H in support of Batch 1 qualification for TCCR 1A. This included two sets of interim samples collected in November during recirculation of the tank, as well as the qualification dip samples received in early December and the in-tank batch contact samples. Density measurements of the two sets of interim samples received in late November 2021 indicated some stratification within the tank, although the difference between the highest and lowest density in the set decreased for the second set of samples. The three dip samples received in early December for batch qualification were not combined but analyzed individually. One sample (HTF-10-21-127) did contain some visible solids and therefore, the analyses were performed on a sample of the filtrate as well as some analyses on a sample of the digested slurry. The average sodium concentration of the three samples was 6.44 M but ranged from 5.46 M in HTF-10-21-126 to 7.00 M in HTF-10-21-127. The total Cs in the dip samples ranged from 5.94 mg/L to 8.68 mg/L, and the ^{137}Cs activity ranged from 1.85E+08 dpm/mL to 2.65E+08 dpm/mL (not including the activity in the digested sample of HTF-10-21-127 which was slightly higher at 2.85E+08 dpm/mL).

A set of four in-tank batch contact samples (two pairs), consisting of 0.1 g of CST contained within teabag devices were also received and characterized by SRNL after being submerged in Tank 10H for a period of 10 days. The CST was rinsed to remove excess salt solution and the CST was then air dried before being digested for analysis. Results of the analysis indicated a ^{137}Cs loading of 6.22E+10 ± 2.08E+09 dpm/g or 28.0 ± 0.939 Ci/kg$_{CST}$ for the upper pair of teabags (B3/B4) and 8.08E+10 ± 8.62E+09 dpm/g or 36.4 ± 3.88 Ci/kg$_{CST}$ for the lower pair of teabags (B5/B6). These values represent bounding upper limits as they include the addition of two sigma uncertainty from replicate analysis of the individual teabag samples as well as the addition of the small amount of ^{137}Cs activity measured in the rinse solutions. The above values are based on the air-dried mass of CST. Correcting to the true dry mass using a F-factor of 0.8107 results in maximum loadings of 34.5 ± 1.16 Ci/kg$_{CST}$ and 44.9 ± 4.79 Ci/kg$_{CST}$ for teabags B3/B4 and B5/B6, respectively. For comparison, these measured loadings are approximately 1.5 – 1.7x (B3/B4)

and 1.9 – 2.2x (B5/B6) higher than ^{137}Cs loadings measured for Batches 1A – 3 of the TCCR demonstration,[16,17,20] which is consistent with the higher Cs concentrations in this batch.

ZAM modeling was performed using the measured composition of the each of the three qualification samples. The modeling of compositions of HTF-10-21-125 and HTF-10-21-127 predicted maximum Cs loadings approximately 1.4x higher than the measured result for the higher loaded teabag set (B5/B6). The predicted Cs loading for the composition of HTF-10-21-126 was higher, ~2x what was measured on the teabags (B5/B6). The lower sodium concentration for HTF-10-21-126 resulted in a higher predicted Cs loading, making the ratio of predicted/measured higher in this case. In general, these are slightly lower ratios (predicted/measured) compared to what was observed for the prior TCCR in-tank batch contact testing performed for Batches 1A – 3 where the ZAM results were always >2x higher than the measured values. However, some of the decrease in predicted loading for these samples may be attributable to the increased sodium concentration used for modeling to create a charged balanced composition. In previous work the measured anion concentrations were typically low compared to the measured cations, and therefore, chloride was typically added in the modeled composition to create a charged balanced solution as chloride is known to have little impact on the Cs loading. In these cases, however, additional sodium was required to create a charge balanced composition and sodium has a significant impact on the predicted Cs loadings.

5.0 References

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[2] K. M. L. Taylor-Pashow, T. Hang, and W. D. King, "Summary of Results from November 2021 Qualification Samples for Tank Closure Cesium Removal 1A (TCCR 1A)", SRNL-STI-2022-00030, Rev. 0, March 2022.
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