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Laboratory Scoping Tests of Decontamination of Hanford Waste Treatment Plant Low Activity Waste Off-Gas Condensate Simulant

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EXECUTIVE SUMMARY

The Hanford Waste Treatment and Immobilization Plant (WTP) Low Activity Waste (LAW) vitrification facility will generate an aqueous condensate recycle stream (LAW Off-Gas Condensate) from the off-gas system. The baseline plan for disposition of this stream is to send it to the WTP Pretreatment Facility, where it will be blended with LAW, concentrated by evaporation and recycled to the LAW vitrification facility again. Alternate disposition of this stream would eliminate recycling of problematic components, and would enable de-coupled operation of the LAW melter and the Pretreatment Facilities. Eliminating this stream from recycling within WTP would also decrease the LAW vitrification mission duration and quantity of glass waste.

This LAW Off-Gas Condensate stream contains components that are volatile at melter temperatures and are problematic for the glass waste form. Because this stream recycles within WTP, these components accumulate in the Condensate stream, exacerbating their impact on the number of LAW glass containers that must be produced. Approximately 32% of the sodium in Supplemental LAW comes from glass formers used to make the extra glass to dilute the halides to acceptable concentrations in the LAW glass, and diverting the stream reduces the halides in the recycled Condensate and is a key outcome of this work. Additionally, under possible scenarios where the LAW vitrification facility commences operation prior to the WTP Pretreatment facility, identifying a disposition path becomes vitally important. This task seeks to examine the potential treatment of this stream to remove radionuclides and subsequently disposition the decontaminated stream elsewhere, such as the Effluent Treatment Facility (ETF), for example. The treatment process envisioned is very similar to that used for the Actinide Removal Process (ARP) that has been operating for years at the Savannah River Site (SRS), and focuses on using mature radionuclide removal technologies that are also compatible with long-term tank storage and immobilization methods. For this new application, testing is needed to demonstrate acceptable treatment sorbents and precipitating agents and measure decontamination factors for additional radionuclides in this unique waste stream.

The origin of this LAW Off-Gas Condensate stream will be the liquids from the Submerged Bed Scrubber (SBS) and the Wet Electrostatic Precipitator (WESP) from the LAW melter off-gas system. The stream is expected to be a dilute salt solution with near neutral pH, and will likely contain some insoluble solids from melter carryover. The soluble components are expected to be mostly sodium and ammonium salts of nitrate, chloride, and fluoride. This stream has not been generated yet and will not be available until the WTP begins operation, but a simulant has been produced based on models, calculations, and comparison with pilot-scale tests.

One of the radionuclides that is volatile and expected to be in high concentration in this LAW Off-Gas Condensate stream is Technetium-99 (^{99}Tc). Technetium will not be removed from the aqueous waste in the Hanford WTP, and will primarily end up immobilized in the LAW glass by repeated recycle of the off-gas condensate into the LAW melter. Other radionuclides that are also expected to be in appreciable concentration in the LAW Off-Gas Condensate are ^{129}I, ^{90}Sr, ^{137}Cs, and ^{241}Am. This report discusses results of preliminary radionuclide decontamination

testing of the simulant. Testing examined use of Monosodium Titanate (MST) to remove ^{90}Sr and actinides, inorganic reducing agents for ^{99}Tc, and zeolites for ^{137}Cs.

Test results indicate that excellent removal of ^{99}Tc was achieved using Sn(II)Cl_2 as a reductant, coupled with sorption onto hydroxyapatite, even in the presence of air and at room temperature. This process was very effective at neutral pH, with a Decontamination Factor (DF) >577 in two hours. It was less effective at alkaline pH. Conversely, removal of the cesium was more effective at alkaline pH, with a DF of 17.9. As anticipated, ammonium ion probably interfered with the Ionsiv®[a] IE-95 zeolite uptake of ^{137}Cs. Although this DF of ^{137}Cs was moderate, additional testing is expected to identify more effective conditions. Similarly, Monosodium Titanate (MST) was more effective at alkaline pH at removing Sr, Pu, and U, with a DF of 319, 11.6, and 10.5, respectively, within 24 hours. Actually, the Ionsiv® IE-95, which was targeting removal of Cs, was also moderately effective for Sr, and highly effective for Pu and U at alkaline pH. The only deleterious effect observed was that the chromium co-precipitates with the ^{99}Tc during the $SnCl_2$ reduction. This effect was anticipated, and would have to be considered when managing disposition paths of this stream.

Results of this separation testing indicate that sorption/precipitation was a viable concept and has the potential to decontaminate the stream. All radionuclides were at least partially removed by one or more of the materials tested. Based on the results, a possible treatment scenario could involve the use of a reductive precipitation agent ($SnCl_2$) and sorbent at neutral pH to remove the Tc, followed by pH adjustment and the addition of zeolite (Ionsiv® IE-95) to remove the Cs, Sr, and actinides. Addition of MST to remove Sr and actinides may not be needed.

Since this was an initial phase of testing, additional tasks to improve separation methods were expected to be identified. Primarily, further testing is needed to identify the conditions for the decontamination process. Once these conditions are established, follow-on tasks likely include evaluation and testing of applicable solid-liquid separation technologies, slurry rheology measurements, composition variability testing and evaluations, corrosion and erosion testing, slurry storage and immobilization investigations, and decontaminated LAW Off-Gas Condensate evaporation and solidification.

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[a] IONSIV is a registered trademark of the UOP LLC Company, Des Plaines, Illinois

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LIST OF ACRONYMNS and ABBREVIATIONS

Avg	Average
CST	Crystalline Silicotitanate
DF	Decontamination Factor
dpm	Disintegrations per minute
ETF	Effluent Treatment Facility
g	grams
h	hour
HLW	High Level Waste
HTWOS	Hanford Tank Waste Operations Simulator
ICP-ES	Inductively Coupled Plasma – Emission Spectroscopy
IDF	Integrated Disposal Facility
IS-MIO	In-Situ Mixed Iron Oxide
L	Liter
LAW	Low Activity Waste
LERF	Liquid Effluent Retention Facility
mg	milligram
mL	milliliter
MST	Monosodium titanate
NM	Not Measured
PA	Performance Assessment
SBS	Submerged Bed Scrubber
SRNL	Savannah River National Laboratory
SRS	Savannah River Site
TIC	Total Inorganic Carbon
µg	micrograms
µL	microliter
µm	micrometer (micron)
WESP	Wet Electrostatic Precipitator
WG	Weapons Grade
WTP	Waste Treatment Plant

1.0 Introduction

The Hanford LAW Off-Gas Condensate stream will be generated in the WTP by condensation and scrubbing of the LAW melter off-gas system by a SBS and WESP, as shown in Figure 1. This stream, which will contain substantial amounts of chloride, fluoride, ammonia, and sulfate ions, will get recycled within the WTP process by return to the Pretreatment Facility where it will be combined with LAW and evaporated. Although the SBS and WESP streams *can* be separately routed to different points in the WTP, they are combined for purposes of this study since they ultimately re-combine at some point within the process. The halide and sulfate components are only marginally soluble in glass, and often dictate the waste loading and thereby impacting waste glass volume. Additionally, long-lived ^{99}Tc and ^{129}I are volatile radionuclides that accumulate in the LAW system, and are challenging to incorporate in glass under the Hanford LAW melter operating conditions. Because ^{99}Tc has a very long half-life and is highly mobile, it is the largest dose contributor to the Performance Assessment (PA) of the IDF [Mann, 2003]. Diverting this LAW Off-Gas Condensate stream to an alternate disposal path would have substantial beneficial impacts on the cost, life cycle, and operational complexity of WTP. "*Much of the load for the Supplemental LAW Facility is caused by internal recycles – namely the halides (chlorine and fluorine) and to a lesser extent sulfur (mostly as sulfates). The halide concentrations can be so high that extra LAW glass needs to be made to accommodate the halides in the glass. Approximately 32 % of the sodium in the supplemental LAW product comes from glass formers used to make the extra glass to dilute halides down to tolerable concentrations.*" [Arakali, 2012]. The objective of this development task is to evaluate decontamination of this stream using sorbents and precipitating agents so that it can be diverted elsewhere (Figure 2). The process would be comparable to the ARP[2] at SRS that has been operating successfully for years, although that process treats tank waste. The concept for this process adapts the use of technically mature absorbents where feasible, such as Monosodium Titanate (MST), commercially available zeolites previously used in radioactive DOE applications, and common industrial chemicals. Use of these inorganic materials is expected to simplify down-stream issues, such as storage and immobilization. Implementation would make available a short-term disposition path if the LAW facility commences operation prior to operation of the Pretreatment Facility and in the long term to divert the stream from recycling. Although the Figure indicates sending the decontaminated liquid to the ETF, other paths may also be identified. The ETF is used here as an example of a potential path that is used for an estimation of decontamination requirements.

The overall plan for technology development of the concentration option, and other options for disposal has been documented [McCabe, 2013]. Other alternative disposal paths are being investigated, including tank farm storage options.

1.1 Simulant Formulation Basis

Because this stream is not yet available for characterization, the simulant formulation was based on input from two sources. The projected solution chemistry and radionuclide content were

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[2] The Actinide Removal Process (ARP) at SRS decontaminates ^{90}Sr and actinides from aqueous tank waste before it is further treated for ^{137}Cs removal by solvent extraction. A small amount of Monosodium Titanate (MST) is added to a batch of decanted tank waste supernate and mixed for 6-12 hours, then filtered with a cross-flow stainless steel filter. The spent MST that is loaded with ^{90}Sr and actinides is washed with water, and sent for vitrification as HLW glass in the DWPF.

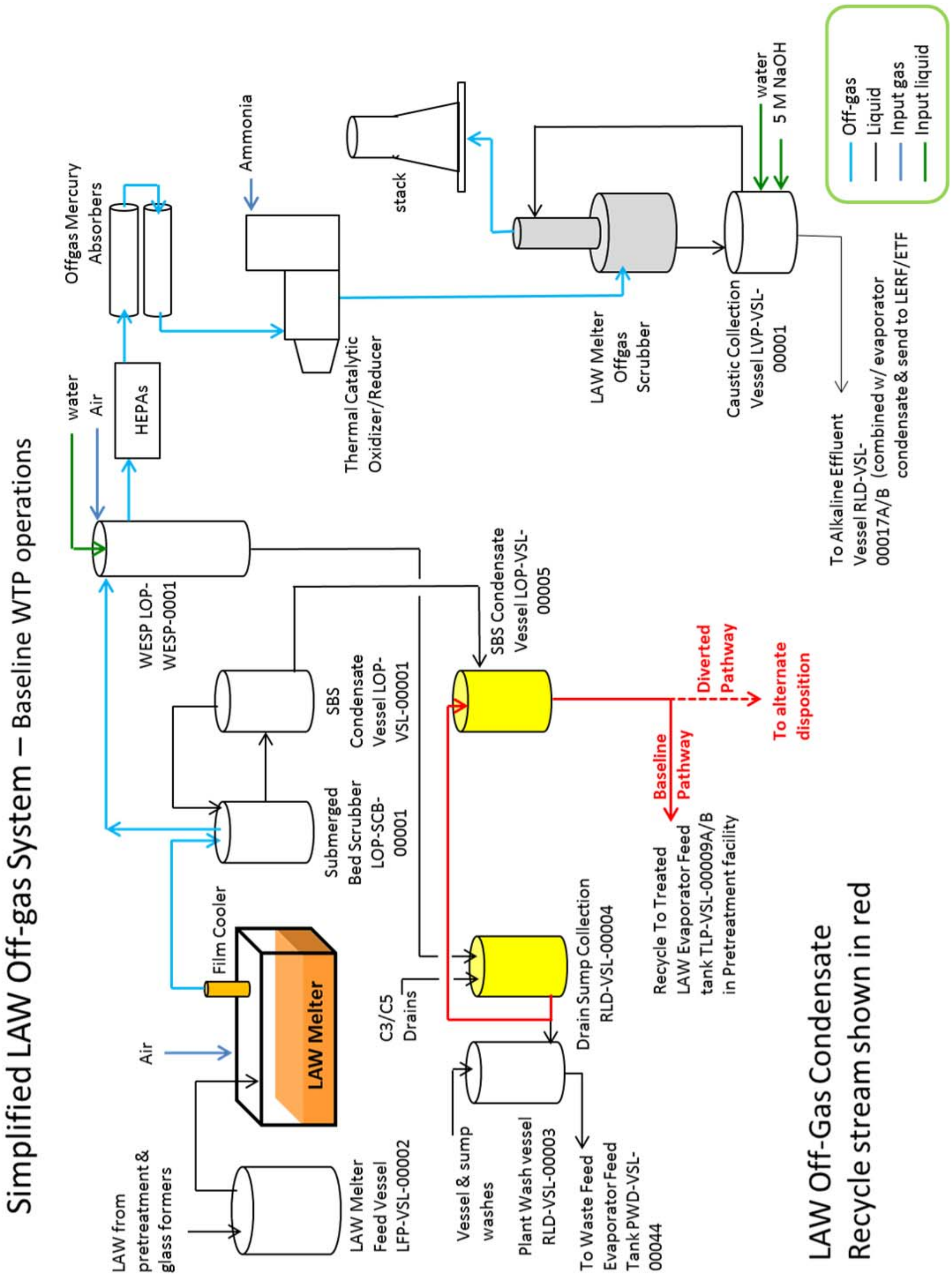

Figure 1 Simplified LAW Off-gas System

(adapted from 24590-WTP-RPT-PT-02-005, Rev. 6); (yellow indicates SBS/WESP LAW Off-Gas Condensate collection tanks, red lines indicate the collected off-gas condensate pathway)

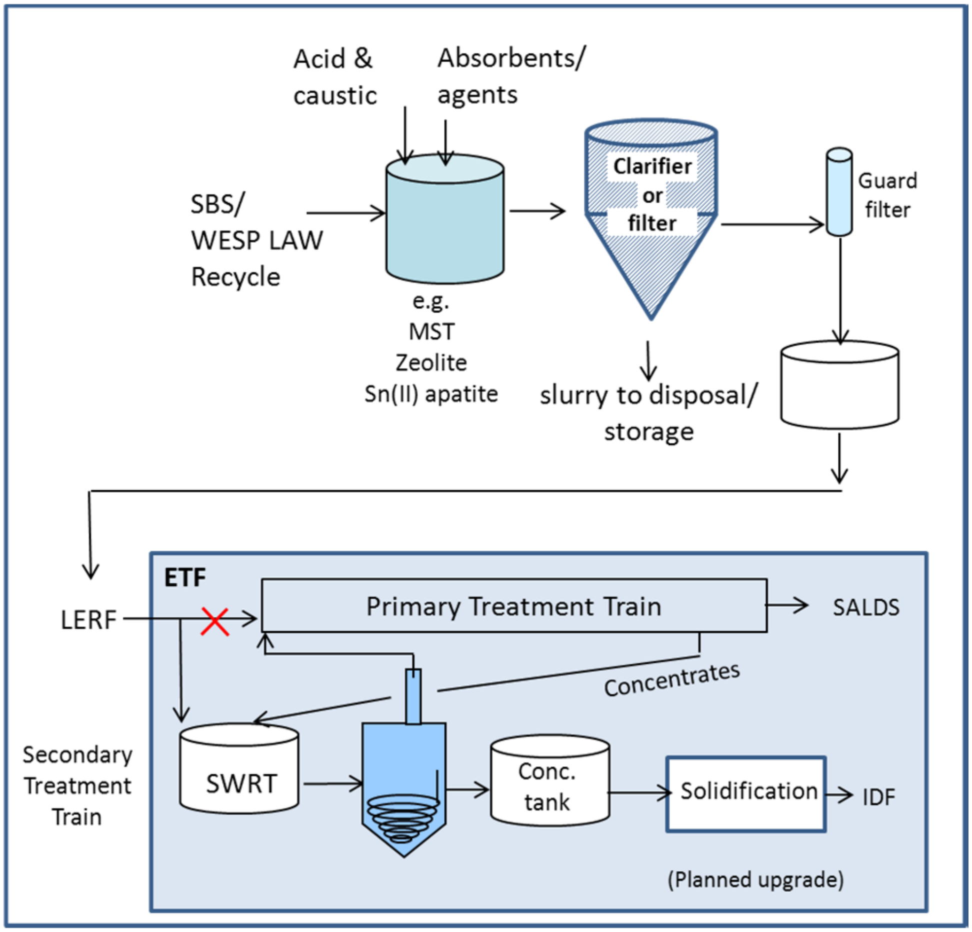

Figure 2 Schematic of a Proposed Decontamination Process and Disposition Path of LAW Off-Gas Condensate

based on version 7.4 of the Hanford Tank Waste Operations Simulator (HTWOS) modeling of the flow sheet [Belsher, 2012] performed by WRPS [SVF-2732]. Insoluble solids composition was primarily based on analysis of LAW Off-Gas Condensate obtained from pilot-scale simulant melter testing [Matlack, 2006]. Basing the solution chemistry and radionuclide content on the computer modeling rather than melter testing results extends the range of compositions and allowed evaluation of process conditions for treatment of all tank wastes. This approach also accounts for internal WTP process streams, making it more comprehensive. However, since the computer model does not account for carryover of solids by physical entrainment, the insoluble solids were based on results from pilot-scale melter off-gas system testing. Those results showed that the insoluble solids were high in iron, indicating that they are largely glass-formers. Therefore, glass formers were added as the insoluble solid phase. After collecting and comparing this information, the major individual components were further assessed by comparison between the measured and computed values, and adjustments were made based on scientific judgment. Further, the composition was evaluated using chemical thermodynamic modeling software to determine potential precipitation of insoluble solids, acid neutralization, and dissolution of glass-former solids. Laboratory testing and analysis dictated the final, actual composition. Potential variability in the waste stream composition was not evaluated yet, but is recommended for later phases of this program. The HTWOS model run scenario selected as the basis for the solution chemistry was full operation of all of the WTP facilities, including second LAW melters, albeit with diversion of the LAW Off-Gas Condensate streams from the LAW melter facilities. This diversion has the effect of lowering the concentration of volatile problematic species (versus the condition where it is recycled and concentrations escalate), but is more realistic of the condition that would be encountered if the stream is diverted from WTP. This test program is an initial scoping phase, and further optimization and compositional ranges will be examined later.

More detail on the synthesis of the simulant has been documented [Adamson, 2013]. The radionuclide contents were based on the HTWOS model run by WRPS [SVF-2732]. Radionuclides selected for inclusion were based on a comparison to the Liquid Effluent Retention Facility (LERF)/ETF limits [McCabe, 2013]. Radionuclides that exceeded the limits were included, except for ^{129}I and ^{151}Sm. The ^{129}I was excluded because current aqueous separation technologies are expected to be overwhelmed by the high halide concentrations, and because the ETF is currently equipped to handle some ^{129}I. Furthermore, since one potential disposition path of the contaminated solids is vitrification, the ^{129}I would vaporize again in the melter, so a more comprehensive evaluation of its fate is needed. The ^{151}Sm was excluded because it is evidently a calculation issue and not expected to actually be present. It is also not appreciably soluble in LAW, based on comparison with SRS waste samples, and would be filtered in High Level Waste (HLW) and not be present in the LAW or LAW Off-Gas Condensate streams.

1.2 Decontamination Process

One option that has been previously evaluated is disposal of the LAW Off-Gas Condensate stream directly to the ETF. This option has a number of consequences to ETF including increases in waste volume, halide levels, and radioactivity [Lueck, 2008; May, 2009]. The amount of halide sent to ETF will increase substantially, which is expected to impact corrosion [Lueck, 2008]. Likewise, the radionuclide content would substantially increase, and would challenge existing treatment capabilities [May, 2009]. If the radionuclides are removed from the Condensate stream in an alternate process and the decontaminated liquid is then sent to the ETF (Figure 2), the fluoride, sulfate, and chloride would be purged from the LAW system, yielding substantial benefits to WTP and mitigating the consequences of radioactive contamination at ETF, but still impacting the operation of ETF due to high halide levels.

The LAW Off-Gas Condensate stream is expected to contain ^{99}Tc due to its volatility at melter temperatures. The only chemical form of ^{99}Tc expected in the stream is pertechnetate anion (TcO_4^-) with a +7 technetium oxidation state. Although some fraction of the ^{99}Tc is present in the initial LAW stream as a soluble “non-pertechnetate” species, the LAW melter is expected to convert it to the same volatile species formed by vitrifying the pertechnetate form, and then become pertechnetate ion again when it contacts the water in the SBS and WESP. (Note that this has not been demonstrated.) The volatile Tc species formed during vitrification has not been determined definitively.

The current WTP baseline assumption is that technetium will not be removed from the aqueous waste in the WTP, and will primarily end up immobilized in the LAW glass waste form after several recycle passes to improve retention [Abramowitz, 2012]. The LAW glass will be disposed in the IDF. Because ^{99}Tc has a very long half-life and is highly mobile [Icenhower, 2008, 2010], it is the major dose contributor to the PA of the IDF [Mann, 2003], even though it is largely retained by the glass. Due to the high water solubility, high volatility during vitrification, and potential for impact to the PA, effective management of ^{99}Tc is important to the overall success of the River Protection Project mission. If a process was implemented that allowed disposal of the radionuclides offsite (e.g. by incorporation into HLW glass instead), the amount of ^{99}Tc disposed in LAW glass at the IDF would decrease substantially.

Other radionuclides have either volatile forms (e.g. ^{129}I) or are carried over as particulates from the melter into the off-gas system, or some combination of both mechanisms. The estimated level of activity and soluble salts in the Condensate stream is expected to generally exceed that in the streams (e.g. evaporator overheads and groundwater) currently processed routinely at the ETF [Lueck, 2008].

For this proposed alternative treatment process, separation of the radionuclides is accomplished by precipitation with chemical reagents, or sorption onto pre-formed materials, and settling and/or filtration, similar to the SRS ARP. For the Condensate stream, emphasis was on using entirely inorganic materials to enable easier storage and disposal as immobilized waste. For technetium removal, these materials included reducing agents (e.g. Sn(II) or Fe(II) compounds) coupled with absorbents (e.g. hydroxyapatite). The Sn(II) with hydroxyapatite and oxalate has previously been found effective for precipitating Tc from water samples [Moore, 2003]. For cesium removal, the primary material tested was zeolites. The strontium and actinide removal was examined using the same MST used at SRS ARP.

For this proposed alternative treatment process, disposal of the aqueous decontaminated Condensate stream at ETF is used as an example pathway. To accomplish this, the stream will be routed to the LERF, and transferred into the Secondary Waste Receiver Tanks in the ETF Secondary Treatment Train (similar to *case 2* in [May, 2009]). Ultimately, disposition of the solidified waste in IDF would likely require a PA calculation. In the absence of such a calculation, constituents that are in appreciable quantities will also be removed by the currently available technology to the extent practical.

The target DF for the radionuclides was derived from comparison of the average calculated composition from the modeling (documented in SVF-2732, shown in Appendix A) versus several acceptance criteria for the Hanford LERF and ETF [McCabe, 2013]. The key radionuclides that exceeded the current limits and their target decontamination factors are shown in Table 1-1. These should all be considered as estimates for the average DF, since they are based on several assumptions of the disposition path and processing steps.

The target DF for ^{137}Cs is based on an estimate of the achievable concentration in the evaporator coupled with the design of the shielding of a future modification planned for immobilizing the concentrate in the ETF. The target DF for ^{99}Tc based on the current established LERF/ETF limits is only 2, but a DF of 100 was arbitrarily selected to minimize the impact of the final disposed waste form from ETF, which is disposed in IDF. The target DF for ^{85}Sr is one because the average Sr concentration in the LAW Off-Gas Condensate stream is beneath the LERF/ETF limits, but the maximum Sr concentration is above it, and would need a DF of ~3. (Note that the isotope used in testing may not be the same isotope that is projected to be in highest concentration in the LAW Off-Gas Condensate stream. For example, ^{85}Sr was used in tests because of its easy gamma analysis versus ^{90}Sr in the stream; similarly, ^{238}U and $^{239/240}$Pu are among the isotopes projected to be present, and all uranium and plutonium isotopes are assumed to have the same DF.)

Table 1-1 Target Decontamination Factors

Isotope	Target DF
^{137}Cs	83
^{238}U	6
$^{239/240}$Pu	2
^{241}Am	166
^{85}Sr	1
^{99}Tc	100

The process is envisioned to be very similar to the equipment used for the SRS ARP, and can utilize designs and lessons learned from that process. The solid-liquid separation equipment may include a clarifier prior to filtration to reduce the burden on the filter and maximize throughput, but that will be determined in a later phase of this program.

The adsorbent/precipitate slurry containing the radionuclides will be characterized in a future phase, and its potential disposition pathways will be evaluated. Immobilization testing will be in a subsequent phase of this program, once the slurry composition and quantities are defined.

2.0 Experimental Procedure

2.1 Simulant Preparation

Detail on the basis and synthesis of the simulant has been documented [Adamson, 2013]. The target concentrations of chemicals and radionuclides were derived from the output from the HTWOS calculation, documented in SVF-2732 and shown in Appendix A. The aqueous phase was prepared from dissolution of laboratory chemicals, as shown in Table 2-1. A single batch of 3.5 L of simulant (i.d.: SBS Sim. batch 3) was prepared and used for the sorbent/reagent tests. The glass formers were then added, and mixed for five days at ambient temperature of ~ 23 ˚C. The filtrate pH was measured to be 8.2 after mixing and was slightly adjusted to a pH of 7.3 ±0.3 with ~ 50 drops of concentrated nitric acid to be within the range measured in pilot-scale testing.

Table 2-1. Aqueous Simulant Formulation

Chemical	Formula	Mass (g)/L simulant
Aluminum nitrate nonahydrate	$Al(NO_3)_3 \cdot 9H_2O$	0.400
Sodium chromate	Na_2CrO_4	0.283
Potassium chloride	KCl	0.219
Sodium chloride	$NaCl$	1.395
Sodium fluoride	NaF	3.209
Ammonium nitrate	NH_4NO_3	4.760
Sodium nitrate	$NaNO_3$	1.221
Sodium nitrite	$NaNO_2$	0.016
Ammonium sulfate	$(NH_4)_2SO_4$	3.220
Dibasic sodium phosphate dihydrate	$Na_2HPO_4 \cdot 2H_2O$	0.040

The glass formers added to the simulant are shown in Table 2-2. Sucrose was excluded because it is destroyed in the melter.

Table 2-2. Glass Formers

Mineral	Formula	Mass (g)/L simulant
kyanite	Al_2SiO_5	0.745
borax	$Na_2B_4O_7 \cdot 10H_2O$	0.0123
boric acid	H_3BO_3	1.430
wollastonite	$CaSiO_3$	0.772
iron oxide (hematite)	Fe_2O_3	0.430
lithium carbonate	Li_2CO_3	0.392
forsterite olivine	Mg_2SiO_4-Fe_2SiO_4	0.257
sodium carbonate	Na_2CO_3	0.003
silica	SiO_2	2.857
rutile	TiO_2	0.114
zinc oxide	ZnO	0.286
zircon	$ZrSiO_4$	0.372
sucrose	$C_{12}H_{22}O_{11}$	0
	Total	7.67

The neutralized simulant containing the glass formers was stirred for several days at room temperature. The solids were then removed by filtration with a 0.45-µm Nalgene®[3] filter. A 1-L portion of the filtrate was then spiked with the radioisotope tracers. Samples were analyzed for elemental composition by Inductively Coupled Plasma – Emission Spectroscopy (ICP-ES), anions and ammonium by Ion Chromatography.

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[3] Nalgene is a registered trademark of the Nalge Company Corporation, Rochester, New York.

2.2 Simulant Spiking with Radionuclides

A 1-L sample of the filtrate was spiked with the radiotracer solutions shown in Table 2-3.

Table 2-3. Radiotracer Solutions added to 1-L of Simulant.

Isotope	Matrix	Amount	Target concentration (dpm/mL)
^{137}Cs	^{137}Cs in 0.1 M HCl	35 µL	1.16E4
^{238}U	$UO_2(NO_3)_2 \cdot 6H_2O$ solid	0.00188 g	6.24E-1
$^{239/240}$Pu	1.5 g/L WG Pu in 0.45 M HNO_3	0.4 µL	6.95E1
^{85}Sr	^{85}Sr radionuclide in 0.5 M HCl	68 µL	5.79E4
^{99}Tc	Ammonium pertechnetate solution	109 µL	9.21E4

After stirring for ~6 days, the 1-L batch was filtered with a 0.45-µm Nalgene® filter. A small amount of white solids were observed. The filtrate was then analyzed for radionuclide contents.

Analysis methods utilized gamma scan (^{137}Cs, ^{85}Sr), Inductively Coupled Plasma – Mass Spectroscopy (^{99}Tc, ^{238}U), and alpha pulse height analysis after an extraction with thenoyltrifluoroacetone ($^{239/240}$Pu). Results are summarized in Section 3 and detailed in Appendix B.

2.3 Sorption/Precipitation Tests

In general, tests were performed by adding a small amount of each sorbent/reagent to separate poly bottles, followed by addition of 20 mL of the radioactive simulant solution to each. The bottles were then agitated in a shaker oven at ~25 ˚C for the specified time (the Tc reduction test samples were sampled at two time points). Each sample was then filtered through a 0.1-µm filter. The filtrate was then analyzed for the radionuclide of interest.

A second set of tests was performed after pH adjustment of the simulant. The simulant (250 mL subsample) was adjusted to pH 12.0 using ~3.1 – 3.2 g of 50 wt% sodium hydroxide solution. The simulant was not filtered prior to contact with the sorbents/reagents, but a control sample was filtered and analyzed to examine the effect of the pH adjustment without any sorbents/reagents. The absorption/precipitation tests were then repeated with the pH-adjusted solution. The mixtures were then filtered, followed by analysis of the filtrate. Results are summarized in Section 3.

Table 2-4 Sorbent/Reagent Test Matrix

Sorbent/Reagent	Mass Phase ratio (liquid g:solid g)	Target quantity	Matrix	Target Duration (hours)
pH = 7.3				
Cs Removal				
Ionsiv® IE-95	100:1	10 g/L	Dry solid	48
CST (Ionsiv® IE-911)	100:1	10 g/L	Dry solid	48
Sr/Actinide Removal				
MST	5000:1	0.2 g/L	14.7 wt% aqueous slurry	24
Tc Removal				
Sn(II) & hydroxyapatite	167:1	3 g/L $SnCl_2$ 3 g/L hydroxyapatite	Dry solid	2, 18
Sn(II) & Na-oxalate	167:1	3 g/L $SnCl_2$ 3 g/L $Na_2C_2O_4$	Dry solid	2, 18
IS-MIO	5000:1	0.1 g/L Fe(II) 0.1 g/L Fe(III)	0.5 M $FeSO_4$ 0.5 M $Fe_2(SO_4)_3$ 0.2 M H_2SO_4	2, 18
pH =12 adjusted Separations				
pH 12 Ionsiv® IE-95	100:1	10 g/L	Dry solid	48
pH 12 MST	5000:1	0.2 g/L	14.7 wt% slurry	24
pH 12 Sn(II) & hydroxyapatite	167:1	3 g/L $SnCl_2$ 3 g/L hydroxyapatite	Dry solid	2, 18
pH 12 ISMIO	5000:1	0.1 g/L Fe(II) 0.1 g/L Fe(III)	0.5 M $FeSO_4$ 0.5 M $Fe_2(SO_4)_3$ 0.2 M H_2SO_4	2, 18

The sources of the sorbents and precipitation reagents were:

IE-95: UOP Ionsiv® IE-95, 20x50 mesh (commercial zeolite)
CST: Crystalline Silicotitanate, UOP Ionsiv® IE-911, batch # 899902081000009 (not caustic washed) (commercial zeolite)
MST ($NaTi_2O_5 \cdot xH_2O$): 14.7 wt% aqueous slurry, Optima batch # 00-QAB-417
Tin(II) chloride dihydrate ($SnCl_2 \cdot 2H_2O$): Fisher chemical, Lot # 096665
Hydroxyapatite ($Ca_5(PO_4)_3OH$): Aldrich chemical, Lot # MKBK2210V
Sodium oxalate ($Na_2C_2O_4$): Aldrich chemical, Lot # 12628KO

IS-MIO (In-situ Mixed Iron Oxide) was prepared by dissolving iron (II) sulfate heptahydrate in 0.4 M H_2SO_4 to prepare a 1 M solution. A 1 M iron (III) sulfate solution was then prepared by dissolving iron (III) sulfate hydrate in distilled water. Just prior to use, equal volumes of each solution were combined to give a 1 M solution of Fe in 0.2 M H_2SO_4.

2.4 Quality Assurance

This test program is described in the Task Technical and Quality Assurance Plan for Developing a Flowsheet for Off-Gas Process Liquids from the Hanford Low Activity Waste Vitrification Process [Wilmarth, 2013]. Requirements for performing reviews of technical reports and the extent of review are established in manual E7 2.60. Savannah River National Laboratory (SRNL) documents the extent and type of review using the SRNL Technical Report Design Checklist contained in WSRC-IM-2002-00011, Rev. 2.

3.0 Results and Discussion

3.1 Simulant Composition

Results of the duplicate chemical analysis of the neutralized, filtered simulant are shown in Table 3-1. These match the target composition (see 'Average Case 1 LAW + 2nd LAW' in Appendix A) reasonably well, although more ammonium was added than the target (~ 18% higher than the 'Average' case and ~ 9% higher than the 'Maximum' case). Future formulations will modify the amount of ammonium added to more closely match the projection, but is expected to not impact results obtained here. The presence of boron, lithium, silicon, and zinc are due to dissolution of the glass former solids. The target concentration for soluble aluminum was ~29 mg/L, or 101 mg/L as $Al(OH)_4^-$ from Appendix A, based on computer modeling and comparison to the pilot scale melter off-gas condensate sample analyses [Matlack, 2006]. However, attempts to dissolve the aluminum (added as 0.4 g/L aluminum nitrate nonahydrate) by manipulation of the sequence of chemical addition and temperature were unsuccessful. One possible explanation for less than detectable soluble Al in this system is formation of cryolite (Na_3AlF_6) precipitate, which along with gibbsite ($Al(OH)_3$), is known to form in various natural water solutions [Roberson and Hem, 1969]. Another possibility is removal by borate. The analyzed soluble fluoride in this system was about 200 mg/L lower (1.25E3 mg/L) than the targeted as-batched fluoride (1.45E3 mg/L).

Table 3-1 Neutralized Simulant Filtrate Chemical Composition

Component	Concentration (mg/L)	Standard Deviation	HTWOS projection (avg. SVF-2732) (mg/L)
Al	<0.100		28
B	253	8	GF[1]
Ca	<0.100		GF
Cr	91.0	0.4	91
Fe	<0.100		GF
K	150	1	115
Li	80.3	0.4	GF
Mg	<0.100		GF
Na	2980	0*	2290
P	<10.0		7 (as PO_4^{-3})
S	832	5	780 (as SO_4^{-2})
Si	52.7	0	GF
Ti	<0.100		GF
Zn	28.6	0.2	GF
Zr	<0.100		GF
F^-	1.25E3	7	1.45E3
Cl^-	934	5	950
NO_2^-	<10		10.7
NO_3^-	4.90E3	21	5.53E3
SO_4^{-2}	2.41E3	0	2.34E3
PO_4^{-3}	<10		21.5
NH_4^+	1.77E3**		1.51E3

*Standard Deviation of zero indicates the two analysis results were identical
**analysis of a single sample
[1] Glass Former component; minimal HTWOS projected concentration

3.2 Decontamination Test Results

Results of the radionuclide analysis results on the initial spiked filtered simulant are shown in Table 3-2.

Table 3-2 Initial Simulant Radionuclide Composition

Isotope	Concentration (dpm/mL)	Reported Method Uncertainty
^{137}Cs	2.50E4	5.0%
^{238}U	6.09E-1	20%
$^{239/240}$Pu	3.91E1	9.0%
^{85}Sr	5.18E4	5.0%
^{99}Tc	9.93E4	20%

Results of the Sorbent/Reagent tests are shown in Tables 3-3 and 3-4. Details of the test results can be found in Appendix B.

Table 3-3 Summary of Results of Sorbent/Reagent Tests (Neutral pH).

Sorbent/Precipitating Agent	**MST**	**IE-95**	**CST (IE-911)**	**Sn(II) & Hydroxyapatite**		**Sn(II) & Na-oxalate**		**IS-MIO**	
Contact Time (h)	**24.2**	**48.0**	**48.1**	**1.98**	**18.2**	**2.00**	**18.2**	**1.98**	**18.2**
Avg. Sr DF	1.29 (0.01)	21.5 (1.70)	44.9 (22.7)	NM	1.64 *(0.12)*	NM	1.27 *(0.09)*	NM	2.58 (0.18)
Avg. Cs DF	0.99 (0.00)	4.32 (0.01)	3.35 (0.57)	NM	0.97 *(0.07)*	NM	0.98 *(0.07)*	NM	0.99 *(0.07)*
Avg. Pu DF	> 1.8†	6.29 *(4.05)*	> 6.00	NM	6.15 *(2.01)*	NM	0.12* *(0.02)*	NM	3.13 *(1.13)*
Avg. Tc DF	0.99 (0.02)	1.00 *(0.28)*	1.01 *(0.28)*	>577	> 577	84.2 (4.17)	50.7 (11.9)	0.99 (0.00)	1.08 (0.00)
Avg. U DF	2.25 (0.51)	2.86 *(0.81)*	2.31 *(0.65)*	1.82 (0.03)	2.07 (0.04)	1.01 (0.03)	1.03 (0.04)	0.97 (0.01)	0.98 (0.02)
Avg. Cr DF	NM	NM	NM	NM	10.1 *(1.47)*	NM	5.65 *(0.81)*	NM	1.49 *(0.21)*

†Duplicate measurements gave very different values, one falling below the method detection limit (DF values of 1.82 and >9.17); *evidently, the Pu analysis was in error

Notes: 1) Outlined boxes indicate target sorbates for each material; yellow highlight indicates exceeded target DF in Table 1-1. 2) Values in parenthesis represent either the standard deviation from duplicate measurements or the method uncertainty for single measurements (italicized values). 3) NM = not measured.

Table 3-4. Summary of Results of Sorbent/Reagent Tests (pH 12).

Sorbent/Precipitating Agent	**MST**	**IE-95**	**Sn(II) & Hydroxyapatite**		**IS-MIO**	
Contact Time (h)	**24.0**	**48.0**	**1.94**	**18.0**	**1.93**	**18.0**
Avg. Sr DF	319 (10.4)	5.32 (1.26)	NM	7.17 *(0.51)*	NM	> 774
Avg. Cs DF	1.01 (0.01)	17.9 (2.39)	NM	1.05 *(0.07)*	NM	1.03 *(0.07)*
Avg. Pu DF	11.6 (12.1)	18.4 *(6.85)*	NM	2.41 *(0.38)*	NM	> 9.96
Avg. Tc DF	1.00 (0.02)	0.98 *(0.28)*	3.35 (0.03)	3.62 (0.10)	1.12 (0.01)	1.13 (0.00)
Avg. U DF	10.5 (0.54)	> 40.3 *(11.4)*	3.02 (1.00)	2.29 (0.45)	5.28 (0.44)	21.2 (3.27)
Avg. Cr DF	NM	NM	NM	5.78 *(0.82)*	NM	1.44 *(0.20)*

Notes: 1) Outlined boxes indicate target sorbates for each material; yellow highlight indicates exceeded target DF in Table 1-1. 2) Values in parenthesis represent either the standard deviation from duplicate measurements or the method uncertainty for single measurements (italicized values). 3) NM = not measured.

In general, the performance of the sorbent materials was greatly influenced by the pH of the simulant. The Sr and actinide removal of MST increased as the pH was increased from 7.3 to 12.0. This was most noticeable for Sr removal, where the MST DF increased from 1.3 to greater than 300. At neutral pH the Ionsiv® IE-95 appeared to slightly outperform the CST (Ionsiv® IE-

911) for Cs removal, and the performance of the Ionsiv® IE-95 increased by a factor of ~4 as the pH was increased to 12. This is consistent with the conversion of ammonium ion, which was expected to interfere with Cs removal on zeolites, to ammonia, which should minimally interfere. The Ionsiv® IE-95 also showed significant affinity for the actinides at pH 12, with DF values higher than those obtained with MST, although this is not a direct comparison because the Ionsiv® IE-95 had 50 times the amount of sorbent and longer contact duration. (Although some of the contact durations in this preliminary phase of testing were longer than desired in a typical process, this testing was designed to measure results at the expected chemical equilibrium duration and for comparison to prior experiments, with process condition optimization much later in the technology maturation phase.)

The Sn(II) reducing agent coupled with hydroxyapatite sorbent worked extremely well for Tc removal at neutral pH. The Sn(II) hydroxyapatite system removed essentially all of the Tc (to below a method detection limit of 5 µg/L) within 2 hours. Using sodium oxalate as a sorbent was less effective. The Tc removal performance was greatly reduced at a pH of 12.0. The IS-MIO did not appear to be an effective Tc removal agent at either pH, but did show excellent Sr and actinide removal at pH 12. This is consistent with previous work showing IS-MIO was effective for removing Sr and actinides from SRS HLW [Poirier, 2004]. As expected, the Sn(II) reductions caused precipitation of chromium, presumably due to reduction of Cr(VI) to Cr(III). IS-MIO evidently reduced some of the Cr(VI) under both pH conditions, so it was not selective to Tc reduction. It may be that higher concentrations of Fe(II) were needed to reduce all of the Cr(VI) before reduction could commence on the Tc.

Removal of Pu and U were more effective at pH 12, with the Ionsiv® IE-95 than with the MST at the sorbent concentrations tested. This result suggests that MST would not be needed, if Ionsiv® IE-95 is used under alkaline conditions for cesium removal.

4.0 Conclusions

Sorption testing with various inorganic sorbents and precipitating agents proved successful for the removal of target sorbates. As expected, the performance of the materials was found to be dependent upon the pH of the simulant. The Sn(II) was much more successful at removal of Tc under near neutral conditions, whereas, the inorganic sorbents (MST and Ionsiv® IE-95) worked much better at pH 12. Since the Sn(II) with hydroxyapatite was much more effective than with sodium oxalate, there is evidently some synergistic effect of both reduction of ^{99}Tc and sorption onto the hydroxyapatite. The Ionsiv® IE-95 was more effective than MST for Sr and actinide removal at neutral pH, and was better for actinides at pH 12. Since the target DF for the average waste composition for Sr was 1 (i.e., no removal for the average), Ionsiv® IE-95 may be adequate for decontaminating this waste stream for Sr and actinides. Additional testing with ^{241}Am is needed, however, to determine if MST is needed. All radionuclides were removed to some extent under the conditions tested. These initial DF targets were met in at least one of the conditions for all measured radionuclides except Cs.

5.0 Future Work

Additional work is needed to further optimize the conditions needed for increased removal, and to further define the DF targets. This preliminary test indicates that the most challenging radionuclide, ^{99}Tc, is easily removed. This was done in two hours using reducing agents without special inert gas controls to prohibit oxygen or manipulation of temperature or pH. Although the chromium was also removed, the total amount of chromium present is small, and could likely be accommodated in the final waste form. Although the IS-MIO was not effective under these conditions, testing at higher concentration of total iron is needed, and may prove effective.

Although the DF target for ^{137}Cs was not met, some manipulation of the parameters would likely improve the removal. Raising the pH slightly higher may have some benefit, or switching to Ionsiv® IE-911 at pH 12 may be sufficient.

Although the optimal pH for removal of Tc is neutral and for removal of Sr and actinides is alkaline, this does not preclude a work-able process. Presumably, the Tc removal with Sn(II)-hydroxyapatite could be performed at neutral pH, followed by pH adjustment and contact with Ionsiv® IE-95 or IE-911. It is likely that solid-liquid removal between the steps would not be needed, although it has not been demonstrated that pH adjustment after removal of Tc would not partially reverse the Tc removal. A single solid-liquid separation of the Sn(II)-hydroxyapatite and Ionsiv® sorbent may suffice. Testing of the sequential concept is needed, along with optimization of the reagent addition, contact durations, measurement of the distribution coefficients, and demonstration of a coupled process. Once these parameters are better defined, testing would be needed on disposition of both the slurry and aqueous phases. Examination of ^{241}Am removal is also needed, but this is likely achievable with MST or one of the Ionsiv® materials.

6.0 References

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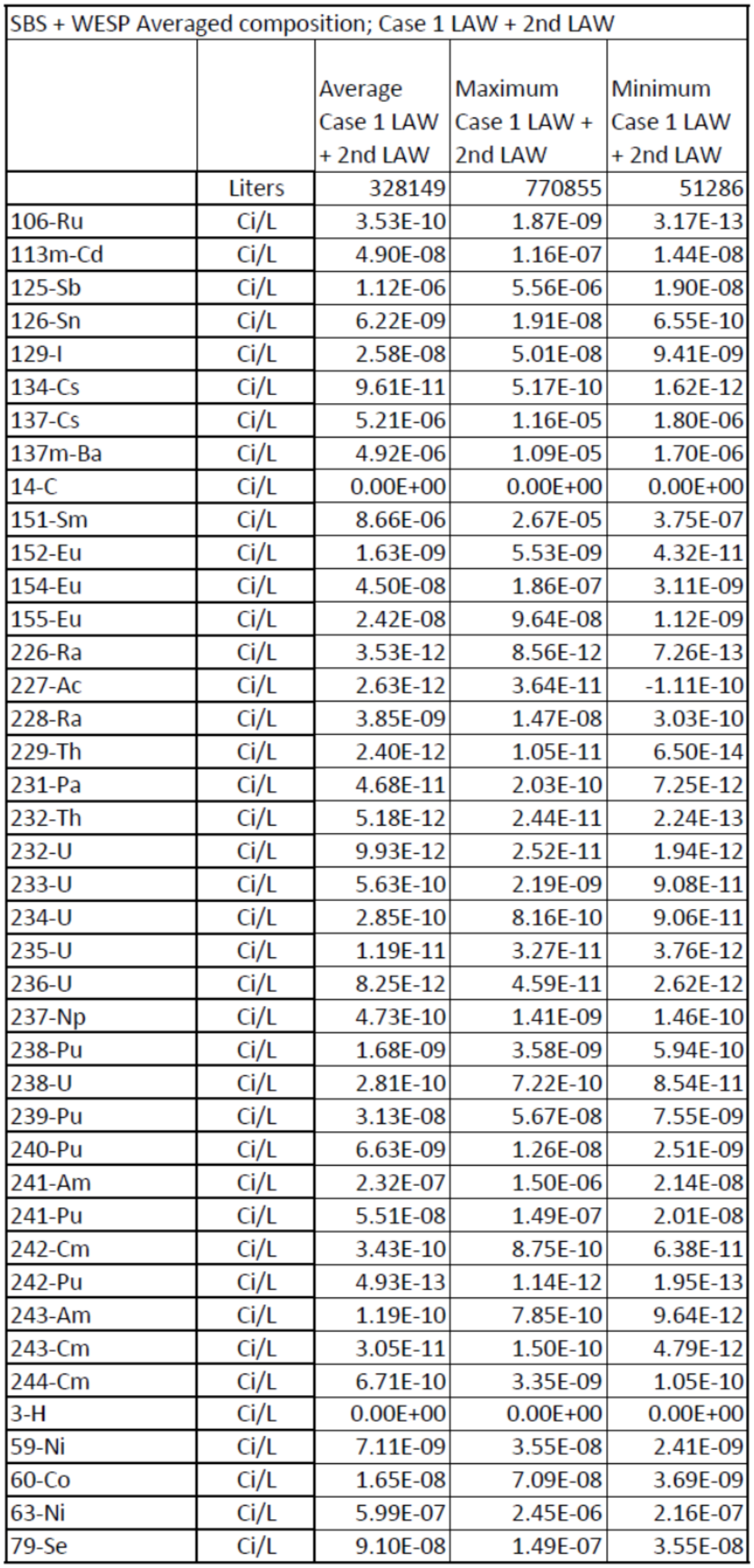
Appendix A. SVF Case 1 Mission averaged Composition;

First LAW and Second LAW

Appendix A contains a preliminary estimate of the SBS/WESP LAW Off-Gas Condensate stream composition [SVF-2732] based on System Plan 7.4. These are from the calculated concentrations per batch, concentration averaged over the entire WTP mission duration.



SBS + WESP Averaged composition; Case 1 LAW + 2nd LAW

		Average Case 1 LAW + 2nd LAW	Maximum Case 1 LAW + 2nd LAW	Minimum Case 1 LAW + 2nd LAW
	Liters	328149	770855	51286
106-Ru	Ci/L	3.53E-10	1.87E-09	3.17E-13
113m-Cd	Ci/L	4.90E-08	1.16E-07	1.44E-08
125-Sb	Ci/L	1.12E-06	5.56E-06	1.90E-08
126-Sn	Ci/L	6.22E-09	1.91E-08	6.55E-10
129-I	Ci/L	2.58E-08	5.01E-08	9.41E-09
134-Cs	Ci/L	9.61E-11	5.17E-10	1.62E-12
137-Cs	Ci/L	5.21E-06	1.16E-05	1.80E-06
137m-Ba	Ci/L	4.92E-06	1.09E-05	1.70E-06
14-C	Ci/L	0.00E+00	0.00E+00	0.00E+00
151-Sm	Ci/L	8.66E-06	2.67E-05	3.75E-07
152-Eu	Ci/L	1.63E-09	5.53E-09	4.32E-11
154-Eu	Ci/L	4.50E-08	1.86E-07	3.11E-09
155-Eu	Ci/L	2.42E-08	9.64E-08	1.12E-09
226-Ra	Ci/L	3.53E-12	8.56E-12	7.26E-13
227-Ac	Ci/L	2.63E-12	3.64E-11	-1.11E-10
228-Ra	Ci/L	3.85E-09	1.47E-08	3.03E-10
229-Th	Ci/L	2.40E-12	1.05E-11	6.50E-14
231-Pa	Ci/L	4.68E-11	2.03E-10	7.25E-12
232-Th	Ci/L	5.18E-12	2.44E-11	2.24E-13
232-U	Ci/L	9.93E-12	2.52E-11	1.94E-12
233-U	Ci/L	5.63E-10	2.19E-09	9.08E-11
234-U	Ci/L	2.85E-10	8.16E-10	9.06E-11
235-U	Ci/L	1.19E-11	3.27E-11	3.76E-12
236-U	Ci/L	8.25E-12	4.59E-11	2.62E-12
237-Np	Ci/L	4.73E-10	1.41E-09	1.46E-10
238-Pu	Ci/L	1.68E-09	3.58E-09	5.94E-10
238-U	Ci/L	2.81E-10	7.22E-10	8.54E-11
239-Pu	Ci/L	3.13E-08	5.67E-08	7.55E-09
240-Pu	Ci/L	6.63E-09	1.26E-08	2.51E-09
241-Am	Ci/L	2.32E-07	1.50E-06	2.14E-08
241-Pu	Ci/L	5.51E-08	1.49E-07	2.01E-08
242-Cm	Ci/L	3.43E-10	8.75E-10	6.38E-11
242-Pu	Ci/L	4.93E-13	1.14E-12	1.95E-13
243-Am	Ci/L	1.19E-10	7.85E-10	9.64E-12
243-Cm	Ci/L	3.05E-11	1.50E-10	4.79E-12
244-Cm	Ci/L	6.71E-10	3.35E-09	1.05E-10
3-H	Ci/L	0.00E+00	0.00E+00	0.00E+00
59-Ni	Ci/L	7.11E-09	3.55E-08	2.41E-09
60-Co	Ci/L	1.65E-08	7.09E-08	3.69E-09
63-Ni	Ci/L	5.99E-07	2.45E-06	2.16E-07
79-Se	Ci/L	9.10E-08	1.49E-07	3.55E-08

Note: 227-Ac minimum is negative in the output, evidently for unknown calculation errors

		Average Case 1 LAW + 2nd LAW	Maximum Case 1 LAW + 2nd LAW	Minimum Case 1 LAW + 2nd LAW
90-Sr	Ci/L	2.61E-05	1.07E-04	1.03E-05
90-Y	Ci/L	2.61E-05	1.07E-04	1.03E-05
93-Zr	Ci/L	9.33E-10	2.64E-09	1.47E-10
93m-Nb	Ci/L	1.05E-07	2.16E-07	3.07E-08
99-Tc	Ci/L	4.15E-05	6.11E-05	1.99E-05
Ag+	g/L	1.46E-05	3.95E-05	6.43E-07
Al(OH)3	g/L	0.00E+00	0.00E+00	0.00E+00
Al(OH)4-	g/L	1.01E-01	1.35E-01	4.97E-02
Al+3	g/L	0.00E+00	0.00E+00	0.00E+00
AlOOH	g/L	0.00E+00	0.00E+00	0.00E+00
As+5	g/L	6.98E-04	1.73E-03	3.87E-05
B+3	g/L	4.22E-05	1.03E-04	2.83E-06
Ba+2	g/L	6.20E-06	1.39E-05	5.83E-07
Be+2	g/L	1.35E-06	7.46E-06	7.87E-08
Bi+3	g/L	2.62E-04	4.66E-04	7.81E-05
C10H12N2O8-4	g/L	0.00E+00	0.00E+00	0.00E+00
C10H15N2O7-3	g/L	0.00E+00	0.00E+00	0.00E+00
C12H27O4P	g/L	0.00E+00	0.00E+00	0.00E+00
C13H28	g/L	0.00E+00	0.00E+00	0.00E+00
C2Cl4	g/L	0.00E+00	0.00E+00	0.00E+00
C2H3O2-	g/L	0.00E+00	0.00E+00	0.00E+00
C2H3O3-	g/L	0.00E+00	0.00E+00	0.00E+00
C2HCl3	g/L	0.00E+00	0.00E+00	0.00E+00
C2O4-2	g/L	0.00E+00	0.00E+00	0.00E+00
C3H6O	g/L	0.00E+00	0.00E+00	0.00E+00
C4H10O	g/L	0.00E+00	0.00E+00	0.00E+00
C4H8O	g/L	0.00E+00	0.00E+00	0.00E+00
C5H5N	g/L	0.00E+00	0.00E+00	0.00E+00
C6H5NO2	g/L	0.00E+00	0.00E+00	0.00E+00
C6H5O7-3	g/L	0.00E+00	0.00E+00	0.00E+00
C6H6	g/L	0.00E+00	0.00E+00	0.00E+00
C7H6N2O4	g/L	0.00E+00	0.00E+00	0.00E+00
C7H8O	g/L	0.00E+00	0.00E+00	0.00E+00
Ca+2	g/L	1.28E-04	2.16E-04	4.95E-05
Cd+2	g/L	2.41E-05	9.60E-05	3.10E-06
Ce+3	g/L	1.75E-03	4.05E-03	2.30E-05
CH2Cl2	g/L	0.00E+00	0.00E+00	0.00E+00
CHCl3	g/L	0.00E+00	0.00E+00	0.00E+00
CHO2-	g/L	0.00E+00	0.00E+00	0.00E+00
Cl-	g/L	9.50E-01	1.13E+00	3.88E-01
CN-	g/L	4.93E-06	8.54E-05	8.85E-09
Co+3	g/L	7.35E-06	1.82E-05	1.48E-06
CO3-2	g/L	0.00E+00	0.00E+00	0.00E+00

		Average Case 1 LAW + 2nd LAW	Maximum Case 1 LAW + 2nd LAW	Minimum Case 1 LAW + 2nd LAW
Cr(OH)4-	g/L	0.00E+00	0.00E+00	0.00E+00
Cr(TOTAL)	g/L	0.00E+00	0.00E+00	0.00E+00
CrO4-2	g/L	2.04E-01	3.09E-01	7.60E-02
CrOOH	g/L	0.00E+00	0.00E+00	0.00E+00
Cs+	g/L	1.29E-07	2.56E-07	4.69E-08
Cu+2	g/L	8.17E-05	4.59E-04	4.73E-06
F-	g/L	1.45E+00	3.70E+00	5.39E-01
Fe+3	g/L	1.47E-04	4.33E-04	3.57E-05
H+	g/L	3.04E-02	1.56E-01	2.79E-02
H2O	g/L	9.98E+02	9.99E+02	9.98E+02
H2O2	g/L	0.00E+00	0.00E+00	0.00E+00
Hg+2	g/L	0.00E+00	0.00E+00	0.00E+00
K+	g/L	1.15E-01	8.17E-01	3.58E-02
La+3	g/L	3.94E-06	1.13E-05	1.03E-07
Li+	g/L	5.30E-06	1.66E-05	3.18E-07
Mg+2	g/L	4.32E-07	1.25E-06	2.29E-08
Mn+4	g/L	3.64E-05	1.04E-04	1.15E-05
MnO2	g/L	0.00E+00	0.00E+00	0.00E+00
MnO4-	g/L	0.00E+00	0.00E+00	0.00E+00
Mo+6	g/L	1.42E-04	3.57E-04	6.46E-06
Na+	g/L	2.29E+00	2.03E+00	1.17E+00
Nd+3	g/L	2.05E-05	6.10E-05	1.20E-06
NH3	g/L	4.38E-03	3.47E-01	1.21E-05
NH4+	g/L	1.51E+00	1.63E+00	4.98E-01
Ni+2	g/L	2.89E-04	1.12E-03	7.20E-05
NO2-	g/L	1.07E-02	2.01E-01	1.79E-306
NO3-	g/L	5.53E+00	6.66E+00	8.57E-01
O(BOUND)	g/L	8.64E-05	2.10E-04	3.93E-06
OH(BOUND)	g/L	0.00E+00	0.00E+00	0.00E+00
OH-	g/L	2.20E-07	1.08E-06	0.00E+00
Pb+2	g/L	3.47E-04	1.16E-03	1.25E-04
Pd+2	g/L	1.95E-05	1.88E-04	7.60E-08
PO4-3	g/L	2.15E-02	4.92E-02	1.20E-02
Pr+3	g/L	1.80E-06	1.07E-05	6.23E-09
Pu+4	g/L	0.00E+00	0.00E+00	0.00E+00
Rb+	g/L	1.17E-06	3.30E-05	3.42E-09
Rh+3	g/L	7.25E-06	5.88E-05	2.44E-08
Ru+3	g/L	7.04E-06	1.25E-04	1.25E-07
Sb+5	g/L	7.06E-04	1.35E-03	5.70E-05
Se+6	g/L	2.90E-03	5.24E-03	7.06E-04
Si+4	g/L	1.03E-03	1.66E-03	3.29E-04
SO4-2	g/L	2.34E+00	4.37E+00	1.22E-03
Sr+2	g/L	2.32E-04	4.73E-03	6.46E-06

		Average Case 1 LAW + 2nd LAW	Maximum Case 1 LAW + 2nd LAW	Minimum Case 1 LAW + 2nd LAW
Ta+5	g/L	6.51E-06	4.03E-05	2.25E-08
Tc+7	g/L	0.00E+00	0.00E+00	0.00E+00
Te+6	g/L	2.37E-04	1.20E-03	4.49E-07
Th+4	g/L	3.82E-08	1.67E-07	1.14E-09
Ti+4	g/L	9.61E-07	2.36E-06	4.74E-08
Tl+3	g/L	6.83E-04	1.83E-03	6.13E-06
TOC	g/L	0.00E+00	0.00E+00	0.00E+00
U(TOTAL)	g/L	0.00E+00	0.00E+00	0.00E+00
V+5	g/L	1.75E-05	4.61E-05	1.57E-06
W+6	g/L	2.31E-05	1.11E-04	2.87E-08
Y+3	g/L	3.18E-06	1.84E-05	1.56E-08
Zn+2	g/L	3.06E-06	1.50E-05	1.43E-07
Zr+4	g/L	5.70E-06	3.43E-05	1.70E-07

Appendix B. Sorbent/Reagent Decontamination Test Detail

Below are the details of the results from the Sorbent/Reagent decontamination tests.

Table 6-1. Summary of Concentration Data from Tests 1-8 (Neutral pH).

Test ID	HLAW-1	HLAW-2	HLAW-3	HLAW-4	HLAW-5	HLAW-6	HLAW-7	HLAW-8
Sorbent	None (Control)	None (Control)	MST	MST	IE-95	IE-95	CST (IE-911)	CST (IE-911)
Sorbent Conc. (g/L)	n/a	n/a	0.2004	0.1998	10.01	10.00	10.02	10.02
Contact Time (h)	24.2	48.0	24.1	24.1	48.0	48.0	48.1	48.0
Sr-85 (dpm/mL)	56,411	55,945	43,823	43,453	2,764	2,472	921	1,947
Cs-137 (dpm/mL)	24,100	23,800	24,100	24,200	5,550	5,540	6,370	8,120
Pu-239/240 (dpm/mL)	22.4	16.1	10.6	< 2.10	3.06	NM	< 3.21	NM
Tc-99 (µg/L)	2,900	2,870	2,870	2,940	2,880	NM	2,870	NM
U-238 (µg/L)	762	756	402	291	265	NM	328	NM
Cr (mg/L)	85.2	85.4	NM	NM	NM	NM	NM	NM

NM = not measured

Table 6-2. Summary of Concentration Data from Tests 9-14 (Neutral pH)

Test ID	HLAW-9	HLAW-10	HLAW-11	HLAW-12	HLAW-13	HLAW-14
Sorbent	Sn(II) & hydroxyapatite	Sn(II) & hydroxyapatite	Sn(II) & Na-oxalate	Sn(II) & Na-oxalate	IS-MIO	IS-MIO
Sorbent Conc. (g/L)	3.016 & 3.012	2.992 & 2.996	2.999 & 3.005	3.014 & 2.998	0.2000 Fe	0.2000 Fe
Contact Time (h)	1.98	1.98	2.00	2.00	1.97	2.00
Tc-99 (µg/L)	< 5.00	< 5.00	35.5	33.1	2,890	2,910
U-238 (µg/L)	422	412	771	740	774	787
Contact Time (h)	18.1	18.2	18.2	18.2	18.2	18.2
Sr-85 (dpm/mL)	34,216	NM	44,349	NM	21,797	NM
Cs-137 (dpm/mL)	24,800	NM	24,500	NM	24,300	NM
Pu-239/240 (dpm/mL)	3.13	NM	164*	NM	6.16	NM
Tc-99 (µg/L)	< 5.00	< 5.00	48.8	68.2	2,680	2,670
U-238 (µg/L)	371	362	715	760	762	781
Cr (mg/L)	8.45	NM	15.1	NM	57.1	NM

*Possible contamination of sample during analysis – results not consistent (higher activity than control).

NM = not measured

Table 6-3. Summary of Concentration Data from Tests 15-20 (pH 12.0).

Test ID	HLAW-15	HLAW-16	HLAW-17	HLAW-18	HLAW-19	HLAW-20
Sorbent	None (Control)	None (Control)	IE-95	IE-95	MST	MST
Sorbent Conc. (g/L)	n/a	n/a	10.01	10.02	0.2009	0.2019
Contact Time (h)	24.0	48.0	48.0	48.0	24.0	24.0
Sr-85 (dpm/mL)	49,903	50,224	8,058	11,289	161	153
Cs-137 (dpm/mL)	24,400	24,600	1,250	1,510	24,200	24,400
Pu-239/240 (dpm/mL)	24.9	86.3	3.02	NM	2.75	18.1
Tc-99 (µg/L)	2,650	2,580	2,670	NM	2,650	2,590
U-238 (µg/L)	832	779	< 20.0	NM	79.9	74.3
Cr (mg/L)	81.5	81.6	NM	NM	NM	NM

NM = not measured

Table 6-4. Summary of Concentration Data from Tests 21-24 (pH 12.0).

Test ID	HLAW-21	HLAW-22	HLAW-23	HLAW-24
Sorbent	Sn(II) & hydroxyapatite	Sn(II) & hydroxyapatite	IS-MIO	IS-MIO
Sorbent Conc. (g/L)	3.001 & 3.004	3.010 & 3.007	0.2000 Fe	0.2000 Fe
Contact Time (h)	1.95	1.93	1.93	1.93
Tc-99 (µg/L)	775	784	2,330	2,350
U-238 (µg/L)	349	216	162	144
Contact Time (h)	18.0	18.0	18.0	18.0
Sr-85 (dpm/mL)	6,986	NM	< 64.7	NM
Cs-137 (dpm/mL)	23,300	NM	23,800	NM
Pu-239/240 (dpm/mL)	23.1	NM	< 5.58	NM
Tc-99 (µg/L)	737	708	2,310	2,310
U-238 (µg/L)	408	308	34.3	42.7
Cr (mg/L)	14.1	NM	NM	56.5

NM = not measured

Distribution:

T. B. Brown, 773-A
M. J. Cercy, 773-42A
D. R. Click, 999-W
D. H. McGuire, 999-W
A. D. Cozzi, 999-W
C. L. Crawford, 773-42A
R. E. Eibling, 999-W
S. D. Fink, 773-A
K. M. Fox, 999-W
C. C. Herman, 773-A
D. T. Herman, 735-11A
E. N. Hoffman, 999-W
C. A. Langton, 773-43A
S. L. Marra, 773-A
D. J. McCabe, 773-42A
C. A. Nash, 773-42A
D. K. Peeler, 999-W
F. M. Pennebaker, 773-42A
K. A. Roberts, 773-43A
M. E. Stone, 999-W
K. H. Subramanian, 241-156H
K. M. L. Taylor-Pashow, 773-A
W. R. Wilmarth, 773-A
Records Administration (EDWS)
J. A. Diediker. DOE-ORP
T. W. Fletcher, DOE-ORP
B. J. Harp, DOE-ORP
C. C. Harrington, DOE-ORP
S. Pfaff, DOE-ORP
A. V. Arakali, WTP
S. M. Barnes, WTP
P. A. Benson, WTP
G. M. Duncan, WTP
S. T. Arm, WRPS
C. Burrows, WRPS
P. Cavanah, WRPS
T. W. Crawford, WRPS
W. G. Ramsey, WRPS
R. A. Robbins, WRPS
P. L. Rutland, WRPS
S. A. Saunders, WRPS
D. J. Swanberg, WRPS
J.B. Duncan, WRPS
M. G. Thien, WRPS
R. A. Peterson, PNNL