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Analyses and Comparison of Bulk and Coil Surface Samples from the DWPF Slurry Mix Evaporator

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EXECUTIVE SUMMARY

Sludge samples from the DWPF Slurry Mix Evaporator (SME) heating coil frame and coil surface were characterized to identify differences that might help identify heat transfer fouling materials. The SME steam coils have seen increased fouling leading to lower boil-up rates. Samples of the sludge were taken from the coil frame somewhat distant from the coil (bulk tank material) and from the coil surface (coil surface sample).

The results of the analysis indicate the composition of the two SME samples are very similar with the exception that the coil surface sample shows ~5-10X higher mercury concentration than the bulk tank sample. Elemental analyses and x-ray diffraction results did not indicate notable differences between the two samples. The ICP-MS and Cs-137 data indicate no significant differences in the radionuclide composition of the two SME samples. Semi-volatile organic analysis revealed numerous organic molecules, these likely result from antifoaming additives. The compositions of the two SME samples also match well with the analyzed composition of the SME batch with the exception of significantly higher silicon, lithium, and boron content in the batch sample indicating the coil samples are deficient in frit relative to the SME batch composition.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AD	Analytical Development
CVHg	Cold Vapor Mercury
DWPF	Defense Waste Processing Facility
ICP-ES	Inductively Coupled Plasma Emission Spectroscopy
ICP-MS	Inductively Coupled Plasma Mass Spectroscopy
SME	Slurry Mix Evaporator
SRNL	Savannah River National Laboratory
St Dev	Standard Deviation
SVOA	Semi-Volatile Organic Analysis
XRD	X-Ray Diffraction

1.0 Introduction

The Slurry Mix Evaporator (SME) tank in the Defense Waste Processing Facility (DWPF) is used to concentrate a mixture of acidified sludge and glass frit prior to feeding to the glass melter. Concentration of the tank contents is accomplished by evaporating water from the product through the use of steam coils. Fouling of the coils has been frequently noted during processing of Sludge Batch 6 and Sludge Batch 7a. The fouling requires the coil to be removed and cleaned, but the bulk of the material fouling the coil has been easily removed with a water spray, with the exception of material between the coils.[1]

DWPF Engineering is evaluating the coil fouling to determine if the fouling is caused by physical processes (such as poor mixing) or chemistry issues (such as formation of aluminum based compounds). Samples were taken from the coil to aid in this evaluation to allow an assessment of whether or not the material on the coil is compositionally similar to the bulk vessel composition.

2.0 Experimental Procedure

Two SME samples (PC0111, bulk tank sample, and PC0109, coil surface sample) were received at SRNL in small metal containers on July 26, 2011. Samples were delivered in doorstops for shielding purposes. The samples of the sludge were taken from the coil frame somewhat distant from the coil (bulk tank material) and from the coil surface (coil surface sample). Figures 2-1, 2-2, and 2-3 contain photographs of the samples. Samples were characterized in duplicate per Table 2-1 below.

Samples of the as-received solids were digested in a sealed Teflon vessel with hot aqua regia by heating to 110 °C. Aliquots of the dissolved solids were submitted to Analytical Development (AD) for analysis by Inductively Coupled Plasma-Emission Spectroscopy (ICP-ES), Inductively Coupled Plasma Mass Spectroscopy (ICP-MS), gamma counting, and mercury using the cold vapor method (CV-Hg).

The sodium peroxide fusion of the samples was performed in a zirconium crucible at a nominal temperature of 675 ºC after first drying the sample overnight at a temperature of 110 ºC. Aliquots of the dissolved solids were submitted to AD for analysis by ICP-ES and ICP-MS.

A small quantity of the as-received solids from each sample was sent to AD for analysis by X-Ray Diffraction (XRD). Another small portion of the as-received solids from each sample were extracted with methylene chloride for Semi-Volatile Organics Analysis (SVOA).

Table 2-1. Characterization Methods

Method	Drying only	Closed vessel aqua regia	Open vessel peroxide fusion
Weight % solids	X		
XRD	X		
ICP-ES		X	X
ICP-MS		X	X
Gamma		X	
CV-Hg		X	
SVOA	*		

* Samples extracted with methylene chloride, no drying

Figure 2-1 As-Received Samples

Figure 2-2 SME Bulk Tank Sample

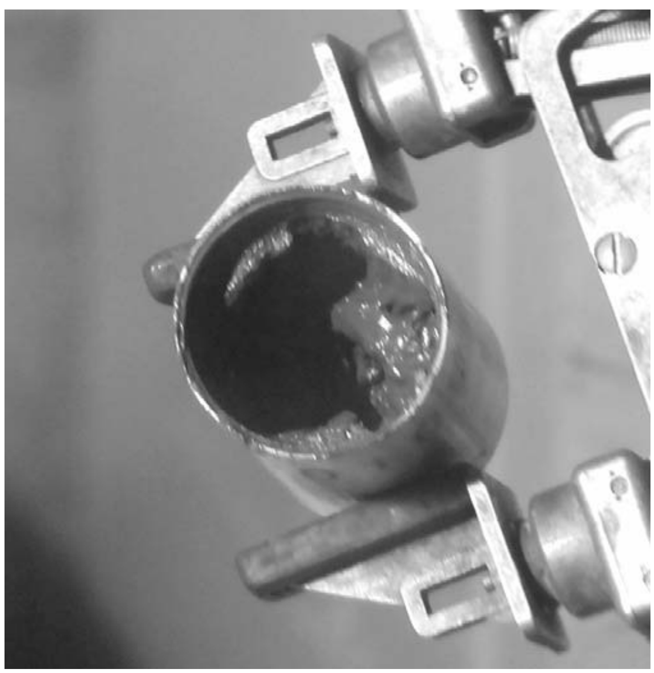

Figure 2-3 SME Coil Surface Sample

3.0 Analytical Results and Discussion

3.1 Results of the Weight Percent Solids and Chemical Analysis of the SME Samples

Table 3-1 shows the results of the weight percent total dried solids analysis of the samples. Both samples contained high solids content with the coil surface sample slightly higher contrary to the appearance of the samples in the photos. The wt% solids values obtained may result from the sampling method and not necessarily reflect the true solids loading of the material as found in the process.

Tables 3-2 and 3-3 show the results of the mercury and Cs-137 analysis of the aqua regia digestion of the as-received solids from the two samples. The gamma scan found roughly similar concentrations of Cs-137 in the two samples. However, the mercury analysis found a ~5-10X higher concentration in the coil surfaces sample than in the bulk tank sample. Both replicates of the coil surface sample showed higher Hg concentrations than the bulk sample replicates. However, replicate A of the coil surface sample was >2X higher than replicate B indicative of inhomogeneity in the sample.

Tables 3-4 through 3-7 provide the results of the ICP-MS analysis of the solids from the samples. Comparing the results from the analysis of the aqua regia digestions for the two samples indicates similar concentrations of uranium and plutonium isotopes in both samples. The results from the peroxide fusion digestion of the two samples also show similar concentrations in both samples.

Tables 3-8 through 3-13 show the results from the ICP-ES analysis of the both aqua regia and peroxide fusion dissolutions of solids from the two SME samples. Both samples contain high concentrations of Si, Fe, Al, Mn, and U. The ICP-ES results from the aqua regia digestion indicate lower silicon concentrations than the peroxide fusion results. The aqua regia method does not dissolve silicon compounds well and can have difficulty dissolving aluminum phases such as Boehmite. As discussed below, the XRD results show the presence of boehmite in the samples, accounting for the low aluminum concentrations determined by the aqua regia digestion. Table 3-14 compares the compositions from the peroxide fusion dissolution of the dried solids from the two samples normalized to Fe. The comparison indicates the two SME samples have very similar elemental compositions.

3.2 X-Ray Diffraction Results

Figures 3-1 through 3-4 show the results of the XRD analysis of the two samples. The XRD identified Hematite (Fe_2O_3) and Boehmite ($AlOH_3$) as the main crystalline phases present in the samples. However, the large broad peaks in all the spectra indicate the presence of unidentified amorphous material in the samples. The Coil Scrape samples also show the presence of some crystalline sodium nitrate. The Muscovite identified in the spectra is found at trace levels in all tank waste samples and can be ignored.

3.3 Semi-Volatile Organic Analysis Results

SVOA work was done mainly to locate and identify organic content of the samples. The results closely match chemicals found in antifoam per a past analysis from Lambert.[2] The appendix provides the list of chemical names, though it is to be recognized that the analysis method produces fragments that may not match the parent antifoam exactly, and process conditions may cause some degradation of the antifoam as well.

Table 3-1. Results of the Weight Percent Total Dried Solids Determination on the SME Samples

Sample	**Bulk PC0111 A wt%**	**Bulk PC0111 B wt%**	**Coil PC0109 A wt%**	**Coil PC0109 B wt%**
Wt% Total Solids	57.9%	57.7%	66.8%	67.0%
Average, %RSD	57.8%, 0.2%		66.9%, 0.2%	

Table 3-2. Results of the Mercury Analysis for the Aqua Regia Digestion of the SME Samples

Sample	**Bulk PC0111 A ug/g**	**Bulk PC0111 B ug/g**	**Coil PC0109 A ug/g**	**Coil PC0109 B ug/g**
CVHg value	501	610	6160	2470
Average, %RSD	556, 14%		4320, 56%	

Table 3-3. Results of the Cs-137 Analysis for the Aqua Regia Digestion of the SME Samples

Sample	**Bulk PC0111 A dpm/g**	**Coil PC0109 A dpm/g**
Cs-137	9.37E+09	6.66E+09

Table 3-4. ICP-MS Results for the Aqua Regia Digestion of the SME Bulk Tank Sample on an As-Received Solids Basis (No Drying).

Analyte	Bulk PC0111-A mg/kg	Bulk PC0111-B mg/kg	Average mg/kg	%RSD
U-235	6.12E+01	5.98E+01	6.05E+01	1.7%
U-238	9.07E+03	8.70E+03	8.89E+03	3.0%
Pu-239	6.32E+01	6.27E+01	6.30E+01	0.5%
Pu-240	6.01E+00	7.12E+00	6.56E+00	12.0%

Table 3-5. ICP-MS Results for the Peroxide Fusion of the SME Bulk Tank Sample on a Dried Solids Basis.

Analyte	Bulk PC0111-A mg/kg	Bulk PC0111-B mg/kg	Average mg/kg	%RSD
U-235	9.71E+01	9.14E+01	9.42E+01	4.3%
U-238	1.28E+04	1.32E+04	1.30E+04	2.0%
Pu-239	8.28E+01	8.23E+01	8.26E+01	0.4%
Pu-240	1.27E+01	1.23E+01	1.25E+01	1.9%

Table 3-6. ICP-MS Results for the Aqua Regia Digestion of the SME Coil Surface Sample on an As-Received Solids Basis (No Drying).

Analyte	Coil PC0109-A mg/kg	Coil PC0109-B mg/kg	Average mg/kg	%RSD
U-235	7.11E+01	6.87E+01	6.99E+01	2.4%
U-238	1.08E+04	1.01E+04	1.04E+04	5.0%
Pu-239	6.56E+01	6.40E+01	6.48E+01	1.7%
Pu-240	5.96E+00	7.07E+00	6.51E+00	12.0%

Table 3-7. ICP-MS Results for the Peroxide Fusion of the SME Coil Surface Sample on a Dried Solids Basis.

Analyte	Coil PC0109-A mg/kg	Coil PC0109-B mg/kg	Average mg/kg	%RSD
U-235	1.00E+02	9.88E+01	9.95E+01	1.0%
U-238	1.47E+04	1.39E+04	1.43E+04	4.1%
Pu-239	8.13E+01	7.40E+01	7.76E+01	6.6%
Pu-240	9.58E+00	1.17E+01	1.07E+01	14.3%

Table 3-8. ICP-ES Results for the Peroxide Fusion of the SME Bulk Tank Sample on an As-Received Solids Basis (No Drying).

Analyte	Bulk PC0111-A mg/kg	Bulk PC0111-B mg/kg	Average mg/kg	%RSD
Ag	<112.0	<135.0	<123.5	-
Al	25600	26200	25900	1.6%
B	1850	1820	1835	1.2%
Ba	290	301	295.5	2.6%
Be	<6.2	<7.5	<6.9	-
Ca	3080	3600	3340	11.0%
Cd	66	70.5	68.25	4.7%
Ce	<549.0	<664.0	<606.5	-
Co	<75.3	<91.2	<83.3	-
Cr	123	124	123.5	0.6%
Cu	123	143	133	10.6%
Fe	34400	35000	34700	1.2%
Gd	148	129	138.5	9.7%
K	<2340.0	<2830.0	<2585.0	-
La	171	167	169	1.7%
Li	4120	4270	4195	2.5%
Mg	1050	1070	1060	1.3%
Mn	10200	10400	10300	1.4%
Mo	<208.0	<252.0	<230.0	-
Ni	4840	4990	4915	2.2%
P	<672.0	<814.0	<743.0	-
Pb	<556.0	<673.0	<614.5	-
S	<5820.0	<7050.0	<6435.0	-
Sb	<828.0	<1000.0	<914.0	-
Si	49000	50100	49550	1.6%
Sn	<436.0	<527.0	<481.5	-
Sr	117	122	119.5	3.0%
Th	3930	4220	4075	5.0%
Ti	195	125	160	30.9%
U	7500	8030	7765	4.8%
V	<36.5	<44.2	<40.4	-
Zn	157	167	162	4.4%

The analytical uncertainty for the ICPES samples is 10%.

Table 3-9. ICP-ES Results for the Peroxide Fusion of the SME Bulk Tank Sample Converted to a Dried Solids Basis.

Analyte	Bulk PC0111-A mg/kg	Bulk PC0111-B mg/kg	Average mg/kg	%RSD
Ag	<188.9	<227.3	<208.1	-
Al	43170.3	44107.7	43639.0	1.5%
B	3119.7	3064.0	3091.9	1.3%
Ba	489.0	506.7	497.9	2.5%
Be	<10.5	<12.7	<11.6	-
Ca	5193.9	6060.6	5627.3	10.9%
Cd	111.3	118.7	115.0	4.5%
Ce	<925.8	<1117.8	<1021.8	-
Co	<127.0	<153.5	<140.3	-
Cr	207.4	208.8	208.1	0.5%
Cu	207.4	240.7	224.1	10.5%
Fe	58010.1	58922.6	58466.3	1.1%
Gd	249.6	217.2	233.4	9.8%
K	<3946.0	<4764.3	<4355.2	-
La	288.4	281.1	284.8	1.8%
Li	6947.7	7188.6	7068.1	2.4%
Mg	1770.7	1801.3	1786.0	1.2%
Mn	17200.7	17508.4	17354.5	1.3%
Mo	<350.8	<424.2	<387.5	-
Ni	8161.9	8400.7	8281.3	2.0%
P	<1133.2	<1370.4	<1251.8	-
Pb	<937.6	<1133.0	<1035.3	-
S	<9814.5	<11868.7	<10841.6	-
Sb	<1396.3	<1683.5	<1539.9	-
Si	82630.7	84343.4	83487.1	1.5%
Sn	<735.2	<887.2	<811.2	-
Sr	197.3	205.4	201.3	2.8%
Th	6627.3	7104.4	6865.8	4.9%
Ti	328.8	210.4	269.6	31.0%
U	12647.6	13518.5	13083.0	4.7%
V	<61.6	<74.4	<68.0	-
Zn	264.8	281.1	273.0	4.2%

The analytical uncertainty for the ICPES samples is 10%.

Table 3-10. ICP-ES Results for the Peroxide Fusion of the SME Coil Surface Sample on an As-Received Solids Basis (No Drying).

Analyte	Coil PC0109-A mg/kg	Coil PC0109-B mg/kg	Average mg/kg	%RSD
Ag	<101.0	<140.0	<120.5	-
Al	27100	27400	27250.0	0.8%
B	3400	3340	3370.0	1.3%
Ba	278	283	280.5	1.3%
Be	<5.6	<7.8	<6.7	-
Ca	4260	3310	3785.0	17.7%
Cd	81.9	79	80.5	2.5%
Ce	<495.0	<685.0	<590.0	-
Co	<67.9	<94.0	<81.0	-
Cr	134	141	137.5	3.6%
Cu	137	141	139.0	2.0%
Fe	37700	37900	37800.0	0.4%
Gd	167	135	151.0	15.0%
K	<2110.0	<2910.0	<2510.0	-
La	172	168	170.0	1.7%
Li	5710	5910	5810.0	2.4%
Mg	1800	1010	1405.0	39.8%
Mn	10900	10500	10700.0	2.6%
Mo	<188.0	<260.0	<224.0	-
Ni	5480	5440	5460.0	0.5%
P	<606.0	<839.0	<722.5	-
Pb	<501.0	<694.0	<597.5	-
S	<5250.0	<7270.0	<6260.0	-
Sb	<746.0	<1030.0	<888.0	-
Si	44300	43700	44000.0	1.0%
Sn	<393.0	<544.0	<468.5	-
Sr	149	122	135.5	14.1%
Th	3660	3670	3665.0	0.2%
Ti	133	149	141.0	8.0%
U	9750	9620	9685.0	0.9%
V	<32.9	<45.5	<39.2	-
Zn	165	171	168.0	2.5%

The analytical uncertainty for the ICPES samples is 10%.

Table 3-11. ICP-ES Results for the Peroxide Fusion of the SME Coil Surface Sample Converted to a Dried Solids Basis.

Analyte	Coil PC0109-A mg/kg	Coil PC0109-B mg/kg	Average mg/kg	%RSD
Ag	<150.3	<209.9	<180.1	-
Al	40327.4	41079.5	40703.4	1.3%
B	5059.5	5007.5	5033.5	0.7%
Ba	413.7	424.3	419.0	1.8%
Be	<8.3	<11.6	<10.0	-
Ca	6339.3	4962.5	5650.9	17.2%
Cd	121.9	118.4	120.2	2.0%
Ce	<736.6	<1027.0	<881.8	-
Co	<101.0	<140.9	<121.0	-
Cr	199.4	211.4	205.4	4.1%
Cu	203.9	211.4	207.6	2.6%
Fe	56101.2	56821.6	56461.4	0.9%
Gd	248.5	202.4	225.5	14.5%
K	<3139.9	<4362.8	<3751.3	-
La	256.0	251.9	253.9	1.1%
Li	8497.0	8860.6	8678.8	3.0%
Mg	2678.6	1514.2	2096.4	39.3%
Mn	16220.2	15742.1	15981.2	2.1%
Mo	<279.8	<389.8	<334.8	-
Ni	8154.8	8155.9	8155.3	0.0%
P	<901.8	<1257.9	<1079.8	-
Pb	<745.5	<1040.5	<893.0	-
S	<7812.5	<10899.6	<9356.0	-
Sb	<1110.1	<1544.2	<1327.2	-
Si	65922.6	65517.2	65719.9	0.4%
Sn	<584.8	<815.6	<700.2	-
Sr	221.7	182.9	202.3	13.6%
Th	5446.4	5502.2	5474.3	0.7%
Ti	197.9	223.4	210.7	8.6%
U	14508.9	14422.8	14465.9	0.4%
V	<49.0	<68.2	<58.6	-
Zn	245.5	256.4	251.0	3.1%

The analytical uncertainty for the ICPES samples is 10%.

Table 3-12. ICP-ES Results for the Aqua Regia Digestion of the SME Coil Surface Sample on an As-Received Solids Basis.

Analyte	Coil PC0109-A mg/kg	Coil PC0109-B mg/kg	Average mg/kg	%RSD
Ag	<81.4	<94.4	<87.9	-
Al	15100	13200	14150	9.5%
B	2840	2950	2895	2.7%
Ba	266	244	255.0	6.1%
Be	1.75	1.84	1.8	3.5%
Ca	2320	2090	2205	7.4%
Cd	97.1	92.1	94.6	3.7%
Ce	161	163	162.0	0.9%
Co	33.3	30.4	31.9	6.4%
Cr	170	141	155.5	13.2%
Cu	134	130	132.0	2.1%
Fe	36900	37500	37200	1.1%
Gd	240	225	232.5	4.6%
K	219	219	219.0	0.0%
La	184	173	178.5	4.4%
Li	4850	4290	4570	8.7%
Mg	1150	1050	1100	6.4%
Mn	10800	10600	10700	1.3%
Mo	21.1	26.2	23.7	15.2%
Na	103000	109000	106000	4.0%
Ni	4900	4650	4775	3.7%
P	442	416	429.0	4.3%
Pb	76.9	83.9	80.4	6.2%
S	1780	2200	1990	14.9%
Sb	<72.1	<83.7	<77.9	-
Si	10900	10100	10500	5.4%
Sn	<31.7	<36.8	<34.3	-
Sr	127	113	120.0	8.2%
Th	4770	4610	4690	2.4%
Ti	68.7	64.2	66.5	4.8%
U	10700	10200	10450	3.4%
V	<2.66	<3.08	<2.9	-
Zn	121	121	121.0	0.0%
Zr	557	545	551.0	1.5%

The analytical uncertainty for the ICPES samples is 10%.

Table 3-13. ICP-ES Results for the Aqua Regia Digestion of the SME Bulk Tank Sample on an As-Received Solids Basis.

Analyte	Bulk PC0111-A mg/kg	Bulk PC0111-B mg/kg	Average mg/kg	%RSD
Ag	<91.1	<110	<100.6	-
Al	7850	6020	6935	18.7%
B	1940	2190	2065	8.6%
Ba	267	285	276	4.6%
Be	1.65	1.75	1.7	4.2%
Ca	2160	2510	2335	10.6%
Cd	84.6	92.4	88.5	6.2%
Ce	187	188	187.5	0.4%
Co	29.1	32	30.6	6.7%
Cr	121	133	127	6.7%
Cu	130	144	137	7.2%
Fe	35000	30400	32700	9.9%
Gd	205	221	213	5.3%
K	232	213	222.5	6.0%
La	164	178	171	5.8%
Li	3750	4160	3955	7.3%
Mg	1080	1170	1125	5.7%
Mn	10700	9410	10055	9.1%
Mo	20.2	22.7	21.45	8.2%
Na	92200	79900	86050	10.1%
Ni	4160	4500	4330	5.6%
P	384	355	369.5	5.5%
Pb	63.9	60.8	62.4	3.5%
S	1560	1730	1645.0	7.3%
Sb	<80.8	<97.1	<89.0	-
Si	4720	4880	4800	2.4%
Sn	<35.5	<42.7	<39.1	-
Sr	112	121	116.5	5.5%
Th	5080	5420	5250	4.6%
Ti	72.4	78.1	75.25	5.4%
U	9540	8280	8910	10.0%
V	<2.97	<3.57	<3.3	-
Zn	118	134	126	9.0%
Zr	513	290	401.5	39.3%

The analytical uncertainty for the ICPES samples is 10%.

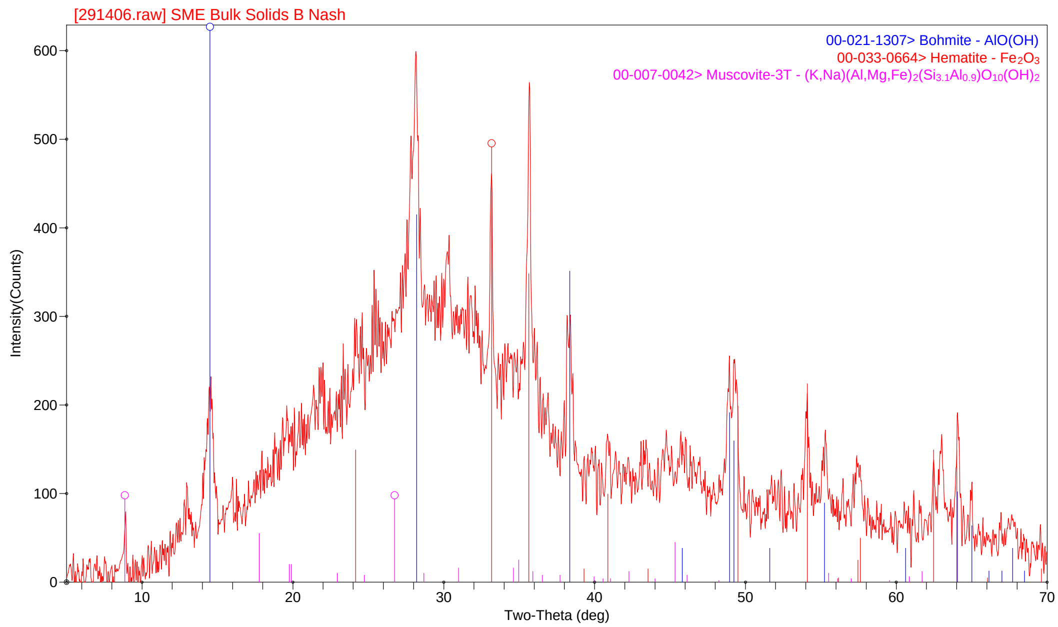

Figure 3-1   XRD Results from Dried SME Bulk Tank Sample A

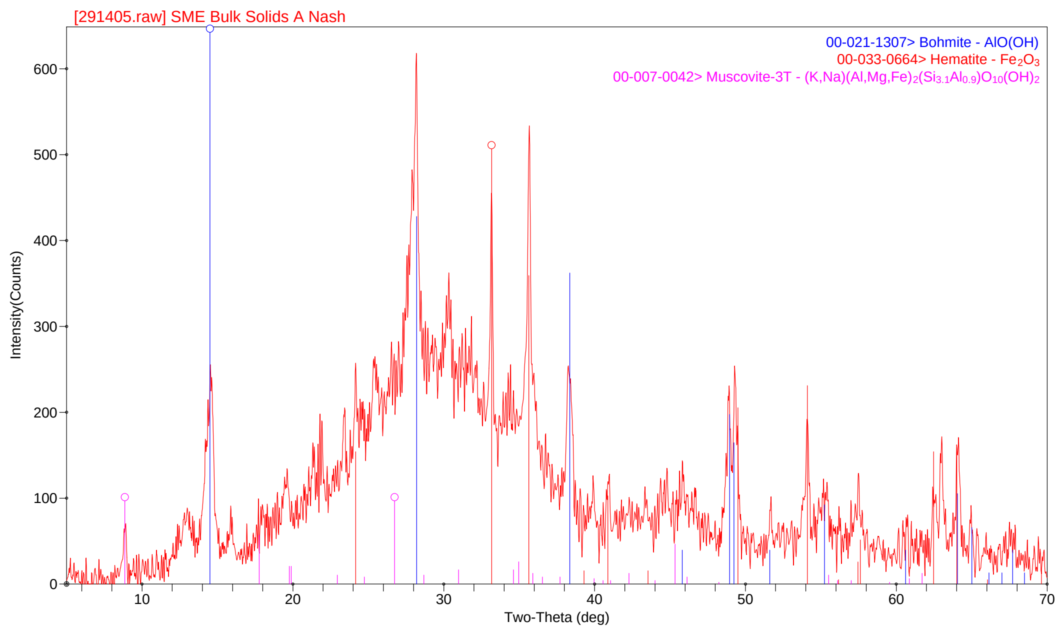

Figure 3-2   XRD Results from Dried SME Bulk Tank Sample B

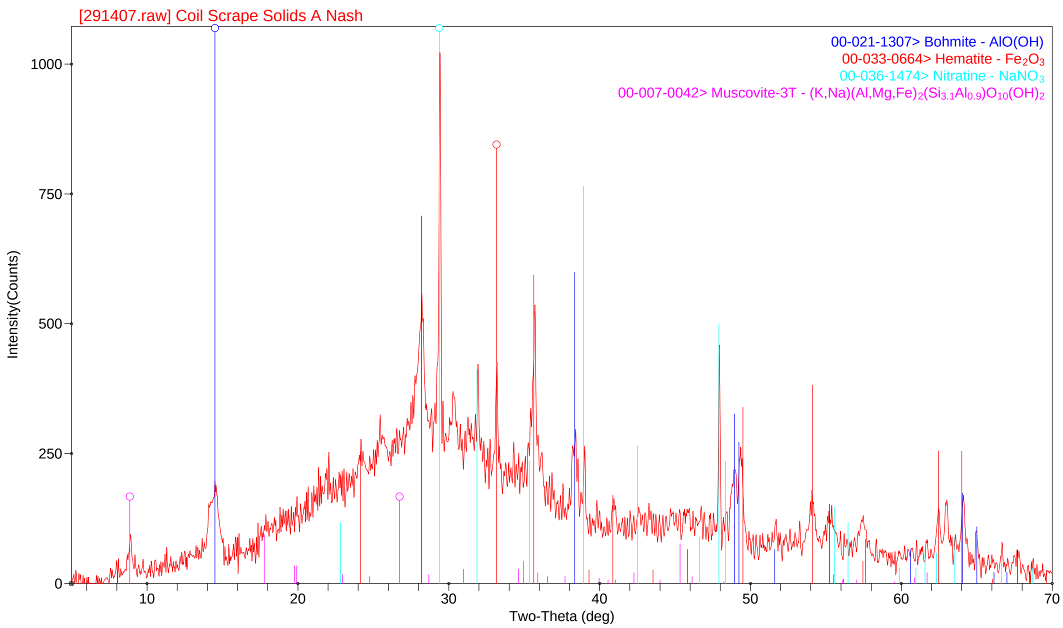

Figure 3-3 XRD Results from Dried SME Coil Surface Sample A

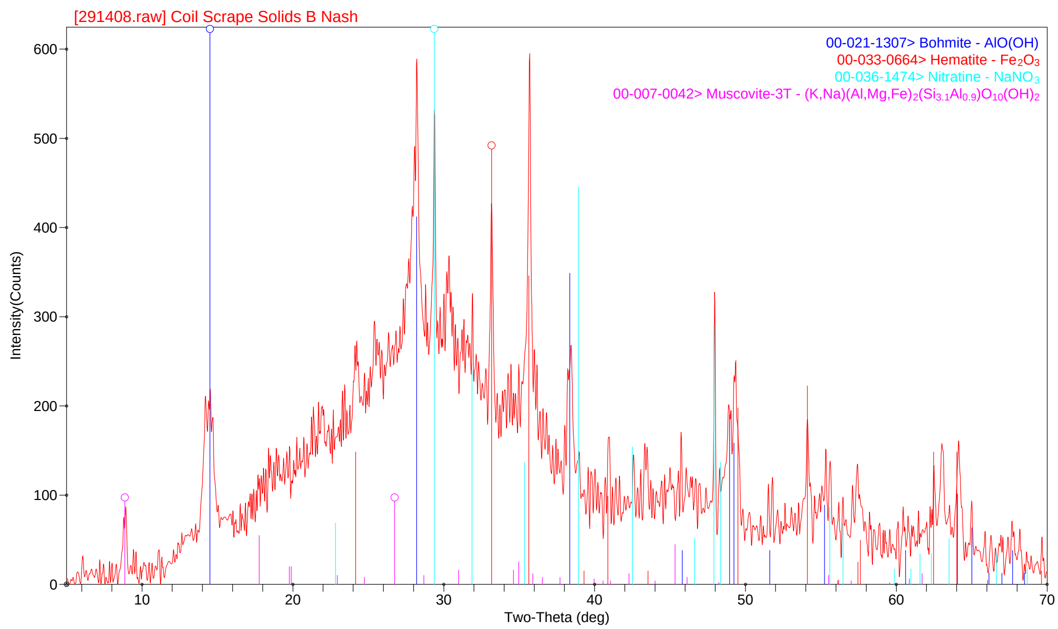

Figure 3-4 XRD Results from Dried SME Coil Surface Sample B

3.4 Discussion of Analytical Results

The analytical results of the two SME samples indicate the compositions of the two samples are very similar. Table 3-14 shows the concentration of the major components of the solids from the peroxide fusion data for the two samples normalized to iron. The bulk sample contains slightly higher silicon but the rest of the metal composition match very closely. The mercury analysis indicates the coils surface sample contains a ~5-10X higher concentration of mercury. The ICP-MS and XRD also indicate the samples have similar compositions.

Table 3-14 also compares the normalized composition of the two SME samples to the batch analysis.[3] All three compositions match reasonably well with the exception that the batch analysis show significantly higher silicon, lithium, and boron content indicating the samples are deficient in frit relative to the SME batch composition.

Table 3-14. Comparison of the SME Bulk Tank Sample, Coil Surface Sample, and SME Batch 583 Compositions on a Dried Solids Basis Normalized to Iron.

Analyte	Bulk PC0111 Average	Coil PC0109-B Average	SME Batch 583
Al	0.746	0.721	0.872
B	0.053	0.089	0.233
Ca	0.096	0.100	0.057
Fe	1.000	1.000	1.000
Li	0.121	0.154	0.336
Mn	0.297	0.283	0.286
Ni	0.142	0.144	0.156
Si	1.428	1.164	3.638
Th	0.117	0.097	0.111
U	0.224	0.256	0.356

4.0 Conclusions

The results of the analysis indicate the composition of the two SME samples are very similar with the exception that the coil surface sample shows ~5-10X higher mercury concentration than the bulk tank sample. Elemental analyses and x-ray diffraction results did not indicate notable differences between the two samples. The ICP-MS and Cs-137 data indicate no significant differences in the radionuclide composition of the two SME samples. Semi-volatile organic analysis revealed numerous organic molecules, these likely result from antifoaming additives. The compositions of the two SME samples also match well with the analyzed composition of the SME batch with the exception of significantly higher silicon, lithium, and boron content in the batch sample indicating the coil samples are deficient in frit relative to the SME batch composition.

5.0 Recommendations for SME Coil Fouling Studies

DWPF engineering, with the assistance of SRNL, has developed a Roadmap[4] identifying all of the potential causes for SME coil fouling and a path-forward to investigate each of those causes. Therefore, SRNL recommends that steps defined in Roadmap be executed as a means of determining the cause and methods to reduce or eliminate the coil fouling.

6.0 References

1. M. C. Clark, J. M. Bricker, A. V. Staub, "Path Forward: Short Term and Long Term Strategy to Address SME Steam Coil Fouling Issues", SRR-WSE-2011-00188, September 22, 2011.

2. D. P. Lambert, "Results for Antifoam 747 Acceptance Testing: Siovation Lot 110684-0413," SRNL-L3100-2011-0086, May 9, 2011.

3. DWPF analytical results for SME Batch 583, August 14, 2011.

4. J. M. Bricker, A. V. Staub, J. E. Occhipinti, "Roadmap: Resolving Coil Fouling Issues in the Slurry Mix Evaporator", SRR-WSE-2011-00231, December 8, 2011.

Appendix A

Table A-1. Identified Organic Components in the DWPF SME Samples.

Organic Analyte	Bulk PC0111-A mg/L	Bulk PC0111-B mg/L	Coil PC0109-A mg/L	Coil PC0109-A mg/L
2-Butanol, 3,3'-oxybis-	0.80	-	-	-
Butanoic acid, 4-methoxy-, methyl ester	-	2.90	-	-
tert-Butyl-[2-[2-(2-methoxyethoxy)ethoxy]ethoxy]dimethylsilane	-	-	0.38	-
tert-Butyl-[2-[2-[2-(2-methoxyethoxy)ethoxy]ethoxy]ethoxy]dimethylsilane	-	-	0.22	-
tert-Butyl-[2-[2-[2-[2-[2-(2-methoxyethoxy)ethoxy]ethoxy]ethoxy]ethoxy]ethoxy]dimethylsilane	-	-	1.00	-
Diisooctyl adipate	4.40	3.70	2.90	3.00
Dipropylene glycol monomethyl ether	0.66	-	0.26	2.90
Ethanol, 2-(2-methoxyethoxy)-	-	0.79	0.59	0.67
Ethane, 1-ethoxy-1-methoxy-	-	-	0.22	-
Ethanol, 2-[2-(2-methoxyethoxy)ethoxy]-	1.70	1.60	1.50	1.30
2-Ethyl-4,6-dimethyl-1,3,5-trioxane	1.40	-	-	1.40
Heptaethylene glycol	0.66	-	-	-
Hexagol	-	2.40	-	0.65
Hexanoic acid, 2-tetradecyl ester	-	2.10	-	-
1,4,7,10,13,16-Hexaoxacyclooctadecane	0.37	-	-	-
2-[2-[2-[2-[2-[2-(2-Hydroxyethoxy)ethoxy]ethoxy]ethoxy]ethoxy]ethoxy]ethanol	-	-	0.61	1.40
2-[2-[2-[2-[2-[2-[2-[2-[2-(2-Hydroxyethoxy)ethoxy]ethoxy]ethoxy]ethoxy]ethoxy]ethoxy]ethoxy]ethoxy]ethoxy]ethanol	-	-	0.34	-
2-[2-[2-(2-Methoxyethoxy)ethoxy]ethoxy]ethanol	-	2.60	1.40	-
2-[2-[2-[2-[2-(2-Methoxyethoxy)ethoxy]ethoxy]ethoxy]ethoxy]ethanol		-	1.70	-
2-[2-[2-[2-[2-[2-(2-Methoxyethoxy)ethoxy]ethoxy]ethoxy]ethoxy]ethoxy]ethanol	-	-	-	1.10
2-[2-[2-[2-[2-[2-[2-(2-Methoxyethoxy)ethoxy]ethoxy]ethoxy]ethoxy]ethoxy]ethoxy]ethanol	-	-	-	1.20
2-[2-[2-[2-[2-[2-[2-[2-(2-Methoxyethoxy)ethoxy]ethoxy]ethoxy]ethoxy]ethoxy]ethoxy]ethoxy]ethanol	1.10	1.00	0.36	0.56
Propane, 1,2,3-trimethoxy-	0.73	-	1.00	-
1-Propanol, 2-(2-methoxy-1-methylethoxy)-	1.37	0.55	1.33	0.74

Table A-1. Identified Organic Components in the DWPF SME Samples (Continued).

Organic Analyte	Bulk PC0111-A mg/L	Bulk PC0111-B mg/L	Coil PC0109-A mg/L	Coil PC0109-A mg/L
2-Propanol, 1-(2-methoxy-1-methylethoxy)-	-	0.29	-	-
2-Propanol, 1-ethoxy-	-	-	-	0.97
1-Propanol, 3,3'-oxybis-	0.26	-	-	-
1-Propanol, 2-(2-hydroxypropoxy)-	0.48	-	1.13	-
Pentaethylene glycol	-	-	0.85	-
2,5,8,11,14-Pentaoxahexadecan-16-ol	0.76	-	1.10	2.40
2,5,8,11,14-Pentaoxapentadecane	0.60	-	-	-
3,6,9,12-Tetraoxahexadecan-1-ol	0.78	-	-	-

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