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Characterization of Tank 23H Supernate Per Saltstone Waste Acceptance Criteria Analysis Requirements-2005

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SUMMARY

Variable depth Tank 23H samples (22-inch sample [HTF-014] and 185-inch sample [HTF-013]) were pulled from Tank 23H in February, 2005 for characterization. The characterization of the Tank 23H low activity waste is part of the overall liquid waste processing activities. This characterization examined the species identified in the Saltstone Waste Acceptance Criteria (WAC) for the transfer of waste into the Salt-Feed Tank (SFT). The samples were delivered to the Savannah River National Laboratory (SRNL) and analyzed.

Apart from radium-226 with an average measured detection limit of < 2.64E+03 pCi/mL, which is about the same order of magnitude as the WAC limit (< 8.73E+03 pCi/mL), none of the species analyzed was found to approach the limits provided in the Saltstone WAC. The concentration of most of the species analyzed for the Tank 23H samples were 2-5 orders of magnitude lower than the WAC limits. The achievable detection limits for a number of the analytes were several orders of magnitude lower than the WAC limits, but one or two orders of magnitude higher than the requested detection limits. Analytes which fell into this category included plutonium-241, europium-154/155, antimony-125, tin-126, ruthenium/rhodium-106, selenium-79, nickel-59/63, ammonium ion, copper, total nickel, manganese and total organic carbon.

INTRODUCTION

The Saltstone Production Facility (SPF) located in Z Area is permitted as a wastewater treatment plant per the South Carolina Pollution Control Act, Title 48, Chapter 1. The aqueous waste is received and treated in the SPF to produce saltstone grout that is then transferred to the Saltstone Disposal Facility (SDF) for final disposal. As presently permitted by the South Carolina Department of Health and Environmental Control (SCDHEC), all transfers of aqueous waste to the SPF shall come through the jacketed pipeline that connects the Tank 50H with the Salt Feed Tank (SFT) in Z Area. The Acceptance Criteria for Aqueous Waste Sent to the Z-area Saltstone Production Facility[1] describes analytical checks required prior to transferring aqueous waste from Tank 50H to the Saltstone Production Facility. Aqueous waste meeting the WAC limits can be safely transferred, stored and treated in the SPF for subsequent disposal as saltstone in the SDF.

Closure Business Unit (CBU) personnel requested analyses on a sample of Tank 23H waste which was pulled on February 15, 2005. The characterization of the Tank 23H low activity waste is part of the overall liquid waste processing activities aimed at the removal and aggregation of the Tank 49H salt solution in Tank 50H and final disposal through the Saltstone Facility of approximately 1,255,000 gallons of low activity waste currently stored in the tank. Thus, before sending low activity Tank 23H material to Tank 50H for

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[1] "Acceptance Criteria for Aqueous Waste Sent to the Z Area Saltstone Production Facility (U)," X-SD-Z-00001, Rev. 2, September7,2004

aggregation purposes, specific measured values for the WAC constituents are required to determined a Tank 23H baseline composition in the aggregation blending evaluation.

The two types of Tank 23H variable depth supernate samples sent to SRNL were contained in either stainless steel dip bottles or liter-size poly-bottles shipped in paint cans. This report describes the work performed to analyze the WAC constituents in the sample pulled from Tank 23H per Technical Task Request number SP-TTR-2004-00025, Rev.1.

EXPERIMENTAL

Of the six stainless steel (SS) bottles containing Tank 23H variable depth samples supplied for organic characterization, three (all identified as HTF-014) contained samples from the 22-inch level of the Tank 23H and the remainder from the 185-inch level of the tank (all identified as HTF-013). Another set of Tank 23H samples were also provided in poly-bottles. These poly-bottles samples contained supernate liquid of approximately 400 mL and were also from the two variable depth samples as described above (HTF-014 and HTF-013). One of the poly-bottle samples, the 22-inch sample (HTF-014), contained some visible solids. See Figure 1 inserts A-C. In consultation with the customer, the solids were filtered off using a 0.45 micron nylon filter prior to compositing of the contents of the poly-bottles. The Tank 23H solids recovered after filtration were less than 1 % by volume of the total sample and were not included in the analysis.

Equal volumes of the SS samples from the 22-inch sample (HTF-014) and 185-inch sample (HTF-013) were composited for organic characterization and the remainder combined with the composited samples from the poly-bottles. (While the use of stainless steel bottles does not fit the EPA protocol for handling samples that potentially contain VOCs, these are used instead of glass vials because of safety considerations with radioactive samples.) This brought the total volume of the Tank 23H composite sample supplied for analysis to approximately 1.8 Liters. The composited sample was divided and submitted to the SRNL Analytical Development Section (ADS) for the required analyses. These samples were analyzed for the analytes specified in Attachments 8.1, 8.2 and 8.3 of the Acceptance Criteria for Aqueous Waste Sent to the Z-area Saltstone Production Facility (WAC) (X-SD-Z-00001, Rev. 2). These analytes are given in Tables 1 and 2 along with the requested detection limit targets and WAC acceptance limits. While target minimum detection limit for each analyte were identified (See target detection limits in Tables -2), ADS personnel were requested to tailor their procedures to attempt meeting the requested limits. All results reported are from the duplicate composite sample (samples 1 and 2).

A number of different analytical methods were used by ADS to determine the concentrations of various species in the samples. Ion chromatography (IC) is used to measure a number of anion species (NO_3^-, NO_2^-, SO_4^{--}, F^-, Cl^-, $C_2O_4^{--}$ and PO_4^{---}) as well as the cation NH_4^+. Carbonate (CO_3^{--}) and free hydroxide were determined by a wet chemistry titration method. Inductively coupled plasma-emission spectrometry (ICP-ES) is used to determine most of the transition metals (Ag, B, Ba, Be, Ca, Cd. Cr, Cu, Mg, Mn, Na, Ni, Pb, Sb, Si, and Zn and others). Atomic Absorption (AA) is used to determine As, Se and K. Acid digestion followed by cold vapor AA (CVAA) technique is used to measure the Hg concentration. Both volatile and semivolatile organic species are determined using gas chromatography coupled with mass spectrometry (GC/MS). Ethylenediamine tetra-acetic acid (EDTA) was determined using ion pair chromatography (IPC). Gas chromatography combined with mass spectrometry (GC/MS) was used to check for most volatile (benzene, butanol and isopropanol) and semi-volatile organic compounds (tributyl phosphate and phenol). There is currently no method available for radioactive samples for methanol analysis. ADS used high pressure liquid chromatography (HPLC) to analyze for sodium tetraphenylborate. Total organic carbon (TOC) was determined using a total organic carbon analyzer. Total suspended solids were measured gravimetrically. A pH meter was used to measure sample pH. Inductively coupled plasma-mass spectrometry (ICP-MS) is used to characterize for ^{237}Np, ^{99}Tc, the uranium isotopes and fission products.

Radionuclide determinations were also made using a number of different methods. Gamma spectrometry was used where possible to determine many radionuclides (^{137}Cs, ^{60}Co, ^{94}Nb, ^{106}Ru/Rh, ^{126}Sn, ^{125}Sb, ^{134}Cs, ^{154}Eu, ^{155}Eu, ^{144}Ce, and ^{94}Nb,). Am/Cm analysis was used to analyze for ^{241}Am, ^{242m}Am and ^{243}Cm. Gross alpha and non-volatile beta determinations were made by first removing the tritium and then using liquid scintillation counting. ^{59}Ni, ^{63}Ni, ^{90}Sr, ^{79}Se, ^{14}C, ^{129}I, and ^{241}Pu were determined by chemical separations followed by beta counting. Tritium was determined by beta counting after separating the tritium by distillation.

It should be noted that the SRNL is not an EPA-approved analytical laboratory for regulatory samples.

Results of Analyses of Tank 23H WAC Samples

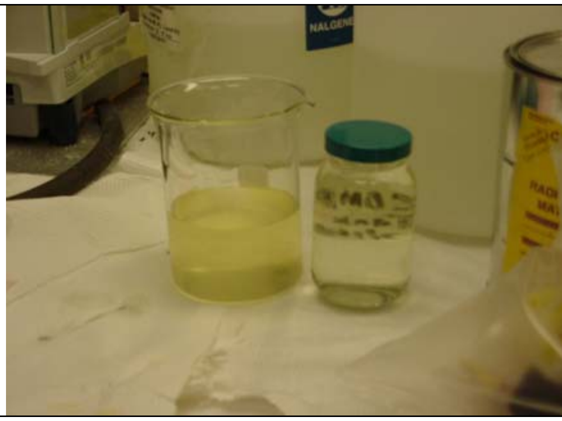
The results of the analyses provided in the tables below for the Tank 23H WAC characterizations are for duplicate analytical determinations by SRNL Analytical Development Section (ADS). For many species the concentration fell below the lower limit of detection. In these cases, ADS reported the lower limit of detection preceded by "<". Tables 1 and 2 provide, respectively, the measured values for chemical contaminants and radionuclides for the Tank 23H samples from the composited variable depth samples (22-inch sample [HTF-014] and 185-inch sample [HTF-013]) pulled in February of 2005, along with the given WAC limits and the plant requested detection limits.

Apart from radium-226 with an average measured concentration of < 2.64E+03 pCi/mL, which is about the same order of magnitude as the WAC limit (< 8.73E+03 pCi/mL), none of the species analyzed was found to exceed the limits provided in the Saltstone WAC. The concentration of most of the species analyzed for the Tank 23H samples were 2-5 orders of magnitude lower than the WAC limits.

It was difficult in some cases to meet the requested detection limits for some species because of dilution and matrix effects problems, especially in those cases where the requested detection limits were quite low and approached the theoretical instrument detection limits with dilution of the samples. This happens to be the case with a number of the analytes whose achievable detection limits were several orders of magnitude lower than the WAC limits, but one or two orders of magnitude higher than the requested limits of detection. Analytes which fell into this category included plutonium-241, europium-154/155, antimony-125, tin-126, ruthenium/rhodium-106, selenium-79, nickel-59/63 ammonium ion, and total organic carbon. The results reported for plutonium-240 are based on 20% of the value obtained for plutonium-239/240 analysis. In those instances when some transition metals (Cd, Pb, Ag and Mo), originally slated to be analyzed by ICP-ES, failed to meet the requested limit due to salt effects the concentration of these metals where obtained directly from the fission product characterization of the samples by ICP-MS. All but a few of the transition metals (Mn, Ni and Cu) met the requested detection limits. Those which did not meet these limits were within about an order of magnitude higher.

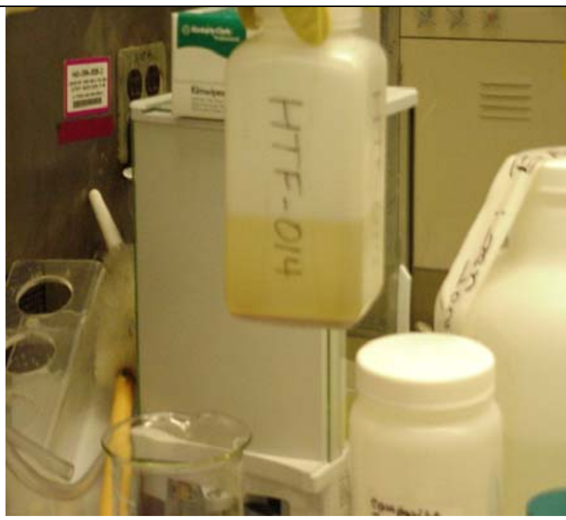
Some radionuclides originally requested for individual analysis in Tank 23H samples (^{152}Eu, ^{227}Ac, ^{249}Bk, ^{229}Th, ^{231}Pa, ^{232}U-mostly minor beta/gamma and alpha emitters) were only bounded by the total alpha and beta/gamma values. In a verbal request, during the Tank 23H analytical characterization process, the plant customer identified these bounding values as sufficient and requested termination of the above radionuclides from further analysis.

The requested limits (last column of Tables 1 and 2) are updated values of the original requested limits as found in the technical task plan (TTP) for this Tank 23H characterizations (WSRC-RP-2005-01299, Rev. 1). Some of the new updated request limits are several orders of magnitude lower than the original requested limits for most of the species analyzed.

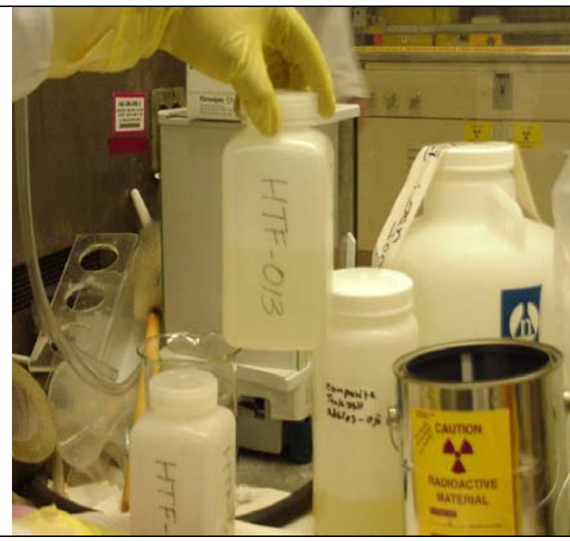


A: Left to right: Beaker with HTF-013 sample from 3 stainless steel containers and jar with HTF-014 sample from 3 stainless steel containers. These two samples composited for organic characterization.

No photograph here.



B: HTF-014 sample in poly-bottles as supplied by the plant. <u>Note brown precipitate on the bottom of the poly-bottle</u>. Sample filtered before compositing.



C: HTF-013 sample in poly-bottles as supplied by the plant. Sample is clear and has no visible particles.

Figure1. Photographs of Tank 23H variable depth samples from the 22 (HTF-014) and 185-inch (HTF-013) levels of the tank.

Table 1. Tank 23H WAC Sample Results for Chemical Contaminants (Units of mg/L except where noted).

Chemical Species	**Sample 1**	**Sample 2**	**Average**	**Stand deviation**	**WAC Limit**	**Requested Detection Limit**
Solvated Ions						
Ammonium (NH_4^+)	< 1.0E+01	< 1.0E+01	< 1.0E+01	-	7.13E+03	7.13E+00
Carbonate (CO_3^{-2})	2.72E+03	2.69E+03	2.71E+03	1.70E+01	1.45E+05	1.45E+02
Chloride (Cl^-)	4.00E+00	4.00E+00	4.00E+00	0.00E+00	9.68E+03	9.68E+00
Fluoride (F^-)	2.00E+00	2.00E+00	2.00E+00	0.00E+00	4.94E+03	4.94E+00
Hydroxide (OH^-)	3.32E+03	2.94E+03	3.13E+03	2.64E+02	1.91E+05	1.91E+03
Nitrate (NO_3^-)	2.44E+03	2.44E+03	2.44E+03	0.00E+00	5.29E+05	5.29E+02
Nitrite (NO_2^-)	9.10E+03	8.92E+03	9.01E+03	1.27E+02	2.59E+05	2.59E+02
Oxalate ($C_2O_4^{-2}$)	1.00E+01	1.10E+01	1.05E+01	7.07E-01	3.30E+04	3.30E+01
Phosphate (PO_4^{-3})	<1.00E+01	<1.00E+01	<1.00E+01	-	3.56E+04	3.56E+01
Sulfate (SO_4^{-2})	9.20E+01	9.30E+01	9.25E+01	7.07E-01	6.89E+04	6.89E+01
RCRA Hazardous Metals						
Arsenic (As)	< 2.80E-02	< 2.80E-02	< 2.80E-02	-	7.50E+02	1.65E-01
Barium (Ba)	2.07E-01	2.47E-01	2.27E-01	2.83E-02	7.50E+02	9.00E-03
Cadmium (Cd)	< 1.64E-02	< 1.28E-02	< 1.46E-02	-	3.75E+02	2.50E-02
Chromium (Cr)	4.09E+00	4.01E+00	4.05E+00	5.66E-02	1.50E+03	1.00E-01
Lead (Pb)	3.01E-01	2.96E-01	2.98E-01	3.08E-03	7.50E+02	6.00E-01
Mercury (Hg)	1.05E+01	9.85E+00	1.02E+01	4.60E-01	3.25E+02	1.00E-01
Selenium (Se)	6.5E-02	6.7E-02	6.60E-02	1.41E-03	4.50E+02	1.00E-02
Silver (Ag)	6.97E-03	1.66E-03	4.31E-03	3.76E-03	7.50E+02	1.10E-02
Other Metals						
Aluminum (Al^{3+})	1.11E+01	1.10E+01	1.11E+01	7.07E-02	1.41E+05	1.00E+00
Boron (B)	1.48E+00	1.57E+00	1.53E+00	6.36E-02	9.00E+02	5.00E-02
Calcium (Ca)	1.48E+00	2.79E+00	2.14E+00	9.26E-01	2.76E+03	1.00E-01
Cobalt (Co)	1.87E-03	1.17E-03	1.52E-03	4.98E-04	9.00E+02	9.00E-01
Copper (Cu)	< 2.00E-01	< 2.00E-01	<2.00E-01	-	9.00E+02	2.00E-02
Iron (Fe)	6.18E-01	1.61E+00	1.11E+00	7.01E-01	6.00E+03	9.00E-02
Lithium (Li)	1.20E+00	1.39E+00	1.30E+00	1.34E-01	9.00E+02	3.00E-02
Manganese (Mn)	< 4.00E-02	< 4.00E-02	< 4.00E-02	-	9.00E+02	3.00E-03
Molybdenum (Mo)	< 5.84E-02	< 5.06E-02	< 5.45E-02	-	9.00E+02	2.00E-01
Nickel (Ni)	<1.86E+00	<1.86E+00	< 1.86E+00	-	9.00E+02	3.20E-02
Potassium (K)	2.32E+01	2.60E+01	2.46E+01	1.98E+00	3.67E+04	1.00E+01
Silicon (Si)	1.61E+02	1.63E+02	1.62E+02	1.41E+00	1.29E+04	1.00E+01
Sodium (Na)	1.22E+04	1.27E+04	1.25E+04	3.54E+02	1.61E+05	1.00E+02
Strontium (Sr)	2.69E-01	6.08E-01	4.39E-01	2.40E-01	9.00E+02	2.00E-02
Zinc (Zn)	2.02E+00	2.10E+00	2.06E+00	5.66E-02	9.75E+02	2.00E-01
Specific gravity	1.03E+00	1.05E+00	1.04E+00	1.41E-02	-	-
pH (pH units)	1.32E+01	1.29E+01	1.31E+01	2.12E-01	-	-
Mean particle size (microns)	7.55E+01	5.50E+01	6.53E+01	1.45E+01	-	-
Suspended Solids (wt %)	5.00E-02	< 1.00E-03	< 2.55E-02	-	15 wt % (1.88E+05 mg/L)	-

Table 1. Tank 23H WAC Sample Results for Chemical Contaminants (Units of mg/L) **continued.**

Chemical Species	**Sample 1**	**Sample 2**	**Average**	**Stand deviation**	**WAC Limit**	**Requested Detection Limit**
Organic Compounds						
Total Organic Carbon	<2.00E+01	<2.00E+01	<2.00E+01	-	5.00E+03	1.00E-01
Butanol & Isobutanol	< 1.0E-01	< 1.0E-01	< 1.0E-01	-	2.25E+03	1.00E-01
Isopropanol	< 5.0E-03	< 5.0E-03	< 5.0E-03	-	2.25E+03	1.00E-01
Methanol	NA	NA	NA	-	2.25E+02	NA
Phenol	< 2.0E-02	< 2.0E-02	< 2.0E-02	-	7.50E+02	7.50E-01
Tetraphenylborate (TPB)	< 2.30E-01	< 2.30E-01	< 2.30E-01	-	3.00E+01	IDL
Toluene	< 5.0E-03	< 5.0E-03	< 5.0E-03	-	3.75E+02	1.00E-02
Tributylphsophate (TBP)	< 2.0E-02	< 2.0E-02	< 2.0E-02	-	3.00E+02	1.00E-02
EDTA	< 1.5E+01	< 1.5E+01	< 1.5E+01	-	3.75E+02	IDL
Benzene	< 5.0E-03	< 5.0E-03	< 5.0E-03	-	-	-

NA = Not available
IDL= Instrument detection limit

Table 2. Tank 23H WAC Sample Results for Radioactive Contaminants (Units of pCi/mL)

Radionuclide	Sample 1	Sample 2	Average	Stand deviation	WAC Limit	Requested Detection Limit
Tritium (^{3}H)	1.00E+03	1.05E+03	1.03E+03	3.54E+01	5.63E+05	1.00E+03
Carbon-14 (^{14}C)	4.26E+01	3.96E+01	4.11E+01	2.07E+00	1.13E+05	1.00E+01
Aluminum-26 (^{26}Al)	< 5.68E-02	< 6.26E-02	< 5.97E-02	-	2.88E+03	1.00E-01
Nickel-59 (^{59}Ni)	< 1.22E+01	< 3.04E+01	< 2.13E+01	-	1.13E+05	1.00E-01
Nickel-63 (^{63}Ni)	< 2.55E+01	< 4.95E+01	< 3.75E+01	-	1.13E+05	1.00E-01
Cobalt-60 (^{60}Co)	8.15E-01	9.05E-01	8.60E-01	6.37E-02	1.13E+06	IDL
Selenium-79 (^{79}Se)	< 4.50E+00	<1.15E+01	< 8.02E+00	-	1.13E+05	1.00E-01
Strontium/Yttrium-90 ($^{90}Sr/Y$)	2.66E+02	3.74E+02	3.20E+02	7.64E+01	2.87E+05	1.00E+01
Niobium-94 (^{94}Nb)	< 5.86E-01	< 6.49E-01	< 6.17E-01	-	1.53E+04	1.00E-01
Technetium-99 (Tc-99)	6.80E+01	6.62E+01	6.71E+01	1.28E+00	4.22E+05	1.00E+01
Ruthenium/Rhodium-106 ($^{106}Ru/Rh$)	< 1.45E+01	< 1.54E+01	< 1.49E+01	-	1.13E+06	1.00E+00
Antimony-125 (^{125}Sb)	< 1.23E+01	< 1.32E+01	< 1.27E+01	-	2.25E+06	1.00E+00
Tin-126 (^{126}Sn)	< 4.86E+00	< 5.14E+00	< 5.00E+00	-	1.80E+04	1.00E+00
Iodine-129 (^{129}I)	4.91E-01	6.67E-01	5.79E-01	1.24E-01	1.13E+03	1.00E-02
Cesium-134 (^{134}Cs)	2.78E+00	2.77E+00	2.77E+00	6.37E-03	1.13E+06	IDL
Cesium-135 (^{135}Cs)	4.23E+00	3.94E+00	4.09E+00	2.02E-01	1.13E+06	IDL
Cesium-137 (^{137}Cs)	5.14E+04	5.54E+04	5.34E+04	2.87E+03	1.40E+06	1.00E+03
Cerium-144 (^{144}Ce)	< 1.18E+01	< 1.25E+01	< 1.21E+01	-	1.13E+05	IDL
Promethium-147 (^{147}Pm)	< 2.01E+00	< 2.85E+00	< 2.43E+00	-	5.63E+06	IDL
Samarium-151 (^{151}Sm)	< 2.90E+00	< 1.54E+00	< 2.22E+00	-	2.25E+04	IDL
Europium-154 (^{154}Eu)	< 9.41E-01	< 1.05E+00	<9.93E-01	-	2.25E+06	1.00E-01
Europium-155 (^{155}Eu)	< 2.67E+00	< 5.95E+00	< 4.31E+00	-	1.13E+04	1.00E-01
Radium-226 (^{226}Ra)	< 2.55E+03	< 2.72E+03	< 2.64E+03	-	8.73E+03	1.00E+01
Thorium-230 (^{230}Th)	< 6.96E+00	< 6.96E+00	< 6.96E+00	-	1.62E+04	IDL
Thorium-232 (^{232}Th)	< 3.62E-05	< 3.62E-05	< 3.62E-05	-	2.88E+03	IDL
Uranium-233 (^{233}U)	< 2.41E+00	< 2.41E+00	< 2.41E+00	-	1.13E+04	IDL
Uranium-234 (^{234}U)	3.63E+00	4.00E+00	3.82E+00	2.62E-01	1.13E+04	1.00E+00
Uranium-235 (^{235}U)	2.43E-02	1.83E-02	2.13E-02	4.24E-03	1.13E+02	9.00E-03
Uranium-236 (^{236}U)	8.80E-02	8.36E-02	8.58E-02	3.11E-03	1.13E+04	1.00E-02
Uranium-238 (^{238}U)	6.64E-01	6.12E-01	6.38E-01	3.68E-02	1.13E+04	1.00E-01

Table 2. Tank 23H WAC Sample Results for Radioactive Contaminants (Units of **pCi/mL**) **continued.**

Radionuclide	**Sample 1**	**Sample 2**	**Average**	**Stand deviation**	**WAC Limit**	**Requested Detection Limit**
Neptunium-237 (^{237}Np)	<1.77E-01	<1.77E-01	<1.77E-01	-	2.25E+04	1.00E-01
Plutonium-238 (^{238}Pu)	1.95E+02	1.92E+02	1.93E+02	2.33E+00	2.25E+04	1.00E+00
Plutonium-239 (^{239}Pu)	8.42E-01	4.79E-01	6.62E-01	2.58E-01	2.25E+04	1.00E-01
Plutonium-240 (^{240}Pu)	2.11E-01	1.20E-01	1.65E-01	6.46E-02	2.25E+04	IDL
Plutonium-241 (^{241}Pu)	< 2.17E+01	< 1.68E+01	< 1.93E+01	-	8.38E+05	1.00E+00
Plutonium-242 (^{242}Pu)	< 9.83E-01	< 9.83E-01	< 9.83E-01	-	2.25E+04	IDL
Americium-241 (^{241}Am)	2.55E+00	2.50E+00	2.53E+00	3.82E-02	2.25E+04	1.00E+00
Americium-243 (^{243}Am)	< 8.24E-02	< 6.08E-02	< 7.16E-02	-	2.25E+04	IDL
Curium-242 (^{242}Cm)	< 1.81E-03	< 1.59E-03	< 1.70E-03	-	1.13E+04	IDL
Curium-243 (^{243}Cm)	< 2.02E-01	< 1.51E-01	< 1.77E-01	-	-	-
Curium-244 (^{244}Cm)	1.03E-01	4.55E-02	7.41E-02	4.05E-02	2.25E+04	IDL
Total Beta/Gamma	7.66E+04	7.25E+04	7.45E+04	2.87E+03	2.37E+07	1.00E+03
Total Alpha	7.03E+02	6.22E+02	6.62E+02	5.73E+01	2.50E+04	1.00E+00
Europium-152 (^{152}Eu)**	-	-	-	-	Total β/γ bound	1.00E+00
Radium-228 (^{228}Ra) **	-	-	-	-	Total β/γ bound	1.00E+00
Actinium-227 (^{227}Ac) **	-	-	-	-	Total β/γ bound	1.00E+01
Berkelium-249 (^{249}Bk) **	-				Total β/γ bound	4.29E+02
Thorium-229 (^{229}Th) **	-	-	-	-	Total α bounded	1.00E+00
Protactinium-231 (^{231}Pa) **	-	-	-	-	Total α bounded	1.00E+00
Uranium-232 (^{232}U) **	-	-	-		Total α bounded	1.00E+00
Plutonium-244 (^{244}Pu)	< 1.0E-02	< 1.0E-02	< 1.0E-02	-	Total α bounded	1.00E+00
Curium-245 (^{245}Cm)	< 1.66E-01	< 1.25E-01	< 1.45E-01	-	Total α bounded	1.00E+00
Curium-247 (^{247}Cm)	< 1.69E-01	< 1.26E-01	< 1.48E-01	-	Total α bounded	1.00E+00
Curium-248 (^{248}Cm)	< 1.40E+00	< 1.40E+00	< 1.40E+00	-	Total α bounded	1.00E+00
Californium-249 (^{249}Cf)	< 1.78E-01	< 1.21E-01	< 1.50E-01	-	Total α bounded	1.00E+00
Californium-251 (^{251}Cf)	< 2.06E-01	< 1.45E-01	< 1.76E-01	-	Total α bounded	1.00E+00
Californium-252 (^{252}Cf)	1.81E-03	< 1.59E-03	< 1.70E-03	-	Total α bounded	1.00E+00

** Not analyzed for at the request of the customer although originally slated to be analyzed.

Distribution

B. H.	Culbertson	704-27S	**(E)**
J. W.	Barber	704-2H, Rm. 197	**(E)**
T. C.	Chandler,	704-Z	**(E)**
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W. M.	Barnes	704-56H, Rm. 164	**(E)**
S. M.	Blanco	766-H. Rm. 2434	**(E)**
L. R.	Bragg	766-H, Rm. 2434	**(E)**
T. E.	Britt	742-4G, Rm. 3	**(E)**
H. L.	Bui	742-4G, Rm. 3	**(E)**
S. G.	Campbell	703-H, Rm. 107	**(E)**
L.	Carey	766-H, Rm. 2005A	**(E)**
J. T.	Carter	703-H, Rm 122	**(E)**
W. D.	Clark	766-H, Rm. 2412	**(E)**
S. L.	Clifford	766-H, Rm. 2443	**(E)**
J. J.	Connelly	773-41A, Rm. 231	**(E)**
D. T.	Conrad	766-H, Rm. 2007	**(E)**
J. W.	Ray	704 -S	**(E)**
A. D.	Cozzi	773-43A, Rm. 218	**(E)**
C. L.	Crawford	773-41A, Rm. 180	**(E)**
D. A.	Crowley	773-A, Rm. A-262	**(E)**
N. R.	Davis	766-H, Rm. 1006	**(E)**
W. B.	Dean	766-H, Rm. 2243	**(E)**
V. G.	Dickert	703-H, Rm. 4	**(E)**
C. L.	Donahue	241-162H, Rm. 6	**(E)**
M. D.	Drumm	766-H, Rm. 2050	**(E)**
M. C.	Duff	773-43A, Rm. 217	**(E)**
C. R.	Dyer	766-H, Rm. 2426	**(E)**
R. E.	Eibling	999-W, Rm. 335	**(E)**
G. N.	Eide	241-121H, Rm. 6	**(E)**
H. H.	Elder	703-H, Rm. 95	**(E)**
S. D.	Fink	773-A, Rm. B-112	**(E, P)**
F. F.	Fondeur	773-A, Rm. B-124	**(E)**
R. C.	Fowler	703-H, Rm. 98	**(E)**
M.W.	Geeting	766-H, Rm. 2035	**(E)**
B. A.	Gifford	766-H, Rm. 1066D	**(E)**
A. P.	Giordano	703-H, Rm 79	**(E)**
J. C.	Griffin	773-A, rm. A-231	**(E)**
H. D.	Harmon	766-H, Rm. 2014	**(P)**
K. D.	Harp	755-H, Rm. 1066B	**(E)**
E. W.	Harrison	766-H, Rm. 2034	**(E)**
K. A.	Hauer	703-H, Rm. 11	**(E)**
D. L.	Hayes	235-H, Rm. 134	**(E)**
D. T.	Herman	735-11A, Rm. 104	**(E)**
P. J	Hill	766-H, Rm. 1066 C	**(E)**
R. N.	Hinds	766-H, Rm. 2430	**(E)**
D. T.	Hobbs	773-A, Rm. B-117	**(E)**
E. W.	Holtzscheiter	773-A, Rm. A-230	**(E)**
C. M.	Jantzen	773-A, Rm. B-104	**(E)**
W. D.	Kerley	766-H, Rm. 2010	**(E)**
E. T.	Ketusky	703-H, Rm. 83	**(E)**
D. P.	Lambert	773-A, Rm. B-132	**(E)**
C. A.	Lanigan	766-H, Rm. 2440B	**(E)**
C. A.	Langton	773-43A, Rm. 219	**(E)**
T. T.	Le	766-H, Rm. 2237	**(E)**
R. K.	Leugemors	766-H	**(E)**
M. S.	Miller	704-S	**(E)**
D. B.	Little	703-H, Rm. 3	**(E)**
N. P.	Malik	704-26F,Rm.11	**(E)**
J. C.	Marra	773-42A,Rm.173	**(E)**
D. J.	Martin	742-4G, Rm. 5	**(E)**
K. B.	Martin	773-42A,Rm.14	**(E)**
C. J.	Martino	735-11A, Rm. 121	**(E)**
G. A.	Mathis	724-9E, Rm. 1	**(E)**
J. E.	Occhipinti	704-S	**(E)**
D.	Maxwell	766-H, Rm. 2231	**(E)**
J. W.	McCullough	766-H, Rm. 2411	**(E)**
L. T.	McGuire	766-H, Rm. 2441	**(E)**
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L. M.	Nelson	773-43A, Rm. 222	**(E)**
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M. R.	Norton	766-H, Rm. 2002	**(E)**
J. E.	Occhipinti	704-S, Rm. 18	**(E)**
L. D.	Olson	703-H, Rm. 5	**(E)**
T. L.	Ortner	766-H, Rm. 2009	**(E)**
L. M.	Papouchado	773-A, Rm. A-263	**(P)**
T. B.	Peters	773-42A, Rm. 128	**(E)**
J. A.	Pike	703-H, Rm. 99	**(E)**
M. R.	Poirier	773-42A, Rm. 123	**(E)**
S. H.	Reboul	703-H, Rm. 84	**(E)**
T. R.	Reynolds	704-S, Rm. 65	**(E)**
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S. J.	Robertson	703-H, Rm. 126	**(P)**
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R. A.	Runnels	766-H, Rm. 2011	**(E)**
P. J.	Ryan	704-61S, Rm. 6	**(E)**
E.	Saldivar	766-H, Rm. 2004	**(E)**
S. C.	Shah	766-H, Rm. 2037	**(E)**
T. J.	Spears	766-H, Rm. 2015	**(E)**
R. H.	Spires	766-H, Rm. 2003	**(E)**
M. E.	Stallings	773-A, Rm. B-117	**(E)**
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