Final Report on Phase III Testing of Monosodium Titanate Adsorption Kinetics

by

D. T. Hobbs

Westinghouse Savannah River Company
Savannah River Site
Aiken, South Carolina 29808

M. G. Bronikowski

T. B. Edwards

R. L. Pulmano

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D. T. Hobbs, 773-A
M. G. Bronikowski, 773-A
T. B. Edwards, 773-42A
R. L. Pulmano, 773-24A

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Westinghouse Savannah River Company
Savannah River Technology Center
Aiken, SC 29808

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Westinghouse Savannah River Company
Savannah River Technology Center
Aiken, SC 29808

Author

D. T. Hobbs 5/30/99
D. T. Hobbs, Waste Processing Technology Section Date

M. G. Bronikowski 6/1/99
M. G. Bronikowski, Chemical and Hydrogen Technology Section Date

Thomas B. Edwards 6/1/99
T. B. Edwards, Statistical Consulting Section Date

Rhena L. Pulmano 6/2/99
R. L. Pulmano, Waste Processing Technology Section Date

Design Check

Darrel D. Walker 6/1/99
D. D. Walker, Waste Processing Technology Section Date
(per Manual E7, Procedure 2.40)

Approvals

Samuel D. Fink 6/2/99
S. D. Fink, Level 4 Manager, Waste Processing Technology Date

J. R. Fowler 6/4/99
J. R. Fowler, Senior Fellow Scientist, HLWE Date

Ray J. Carter 6/28/99
J. T. Carter, Manager, HLW Processing Engineering Date

W. L. Tamosaitis 6/30/99
W. L. Tamosaitis, Level 3 Manager, Waste Processing Technology Date

Summary

Testing examined the effects of ionic strength (i.e., 4.91, 6.55 and 8.20 M or at a Na^+ concentration of 4.5, 6.0 and 7.5 M), temperature (i.e., 25, 45 and 65 °C), mixing (i.e., 0, 200 and 700 rpm), sludge solids (i.e., 0 and 400 mg/L), and sodium tetrphenylborate (i.e., NaTPB at 0 and 400 mg/L) on the extent and rate of strontium, plutonium, neptunium and uranium removal by adsorption onto monosodium titanate (MST). The tests examined performance at different concentrations of strontium (4.96 to 106 $\mu\text{g/L}$), plutonium (0.56 to 280 $\mu\text{g/L}$), uranium (1520 to 26000 $\mu\text{g/L}$) and neptunium (340 to 35800 $\mu\text{g/L}$) in simulated high-level waste solutions containing different masses of MST.

The more important parameters affecting sorption include initial sorbate concentration, MST concentration, ionic strength and temperature. The presence of NaTPB did not significantly affect the removal of any sorbate. Strontium, plutonium and uranium removal increased slightly in the presence of synthetic sludge solids. Strontium and plutonium removal, but not uranium and neptunium removal, decreased slightly in tests when the only mixing involved shaking for sampling. Moderate versus vigorous mixing did not affect removal of strontium, plutonium or neptunium (uranium not determined). The affects of mixing and sludge solids proved small compared to those observed for initial sorbate concentration, MST concentration, ionic strength and temperature.

Testing results indicated successful decontamination of a 4.5 M Na^+ salt solution within Z-Area limits for Sr-90, total alpha activity and Np-237 by adding 0.2 g/L MST. At the higher sodium ion concentration (7.5 M Na^+), the equilibrium concentrations did not always satisfy Z-Area limits indicating a higher MST concentration is required at higher ionic strength.

Removal rates determined at the lowest MST concentration provide data for sizing continuously stirred tank reactors and batch tanks for the various Salt Disposition Alternative flowsheets. Qualitatively, the removal rates appear sufficiently rapid for any of the alternatives. We recommend additional testing with simulants at lower neptunium concentrations and with radioactive waste to confirm the results of this testing.

From statistical analysis of the data, the authors derived equations for predicting the equilibrium solution concentrations for each sorbate. Models for strontium, uranium and neptunium exhibited good fits as evidence by high correlation coefficients ($r^2 > 0.97$). We attribute the poorer fit for the plutonium results ($r^2 = 0.789$) to the large number of equilibrium concentrations falling below the detection limits of the analytical methods. We recommend further analysis of the composite data -- following the additional recommended tests -- using available adsorption models (e.g., Freundlich and Langmuir) to develop better predictive models of this multi-sorbate system.

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Introduction

The Salt Disposition Systems Engineering Team identified the adsorption kinetics of actinides and strontium onto monosodium titanate (MST) as a technical risk for several of the processing alternatives selected for evaluation in Phase III of their effort. The Flow Sheet Team requested that the Savannah River Technology Center (SRTC) examine the adsorption kinetics of MST for several process alternatives [1].

Previously, Hobbs and Walker studied the adsorption of plutonium and uranium onto MST in alkaline solutions [2]. Results of these tests indicate that MST would remove strontium, uranium and plutonium from simulated In-Tank Precipitation (ITP) waste solutions. Hobbs and Fleischman followed with statistically designed testing to examine temperature and chemical composition [3]. Again, the results clearly indicate that MST would sufficiently remove strontium, uranium and plutonium. However, the previous studies did not examine the kinetics of the adsorption process.

This study consisted of a statistically designed set of tests to determine the extent and rate of adsorption of strontium, plutonium, uranium, and neptunium as a function of temperature, MST concentration, and concentrations of sodium, strontium, plutonium, uranium and neptunium. Additional tests incorporated into the design assess the effects of mixing as well as the influence from the presence of sludge solids and sodium tetraphenylborate. The Statistical Consulting Section of SRTC assisted in the design of experiments [4].

Experimental

Preparation of Treated Salt Solution

Personnel prepared 10 liters of a synthetic salt solution from reagent grade chemicals and deionized, distilled (DDI) water yielding the composition provided in Table I. The composition of the salt solution is scaled to that previously used in MST testing of actinide loading and maximizes solubility of plutonium and uranium [5]. Filtering of undissolved solids occurred using Whatman #1 filter paper. Researchers then mixed the filtered solution with 133 grams of MST slurry (20 grams MST, Optima Batch #33407), and stirred the resulting mixture at laboratory temperature for 48 hours before filtering it through a medium porosity sintered-glass funnel to remove strontium impurities present in the reagent grade chemicals. They repeated this MST treatment using 15 grams of MST slurry (2.3 grams MST, Optima Batch #33407), stirring the mixture at ambient laboratory temperature for 72 hours and filtering it through a medium porosity sintered glass funnel. Inductively coupled plasma mass spectrometry (ICP-MS) analysis of the treated solution indicated a strontium concentration of 0.096 mg/L.

Table I. Composition of Salt Solution

<u>Component</u>	<u>Concentration (M)</u>
NaNO ₃	3.47
NaOH	1.78
Na ₂ SO ₄	0.694
NaAl(OH) ₄	0.572
NaNO ₂	0.178
Na ₂ CO ₃	0.0347
Total Na ⁺	7.46

Preparation of High Activity Salt Solutions

Researchers placed 4.8 L of the treated salt solution in a clean 8-L polyethylene (PE) carboy. Next, personnel added 5.0 mL of a nitric acid solution containing 22.13 mg/mL uranium, 1.12 mg/mL plutonium and 50.2 mg/mL neptunium and 0.100 mL of a solution containing 104 mg/mL strontium nitrate. The solution stirred at ambient laboratory temperature for 11 days. Next, the test method required pipetting 1.00 mL of Sr-85 (New England Nuclear, NEZ082, 9.03 mCi/mg Sr) in hydrochloric acid (0.28 mCi/mL) into the solution and stirring overnight. The researchers then pipetted 0.50 mL of Sr-85 in hydrochloric acid (0.28 mCi/mL) into the solution and stirred it overnight before filtering it through a 0.45- μ m pore size, disposable (cellulose nitrate) membrane filter. Personnel then pipetted 1.00 mL of Sr-85 in hydrochloric acid (0.28 mCi/mL) into the solution and stirred overnight. The final addition used 1.50 mL of Sr-85 in hydrochloric acid (0.28 mCi/mL) followed by 3 days of agitation. Finally, researchers filtered the suspension through a 0.45- μ m pore size, disposable (cellulose nitrate) membrane filter and stored in a clean 8 L PE carboy labeled as "7.5 M High".

Researchers prepared a "6.0 M High" stock by adding distilled, deionized water to a sufficient amount of the 7.5 M High solution in a clean PE bottle to produce 2.75 L of solution with a final sodium concentration of 6.0 M. Similarly, researchers prepared 1.5 liters of a "4.5M High" stock by dilution.

Preparation of Low Activity Salt Solutions

Researchers placed 4.8 L of the treated salt solution in a clean 8 L PE carboy and added 0.400 mL of a nitric acid solution containing 22.13 mg/mL uranium, 1.12 mg/mL plutonium and 50.2 mg/mL neptunium. The solution stirred for 11 days at ambient temperature. Personnel then pipetted 1.00 mL of Sr-85 in hydrochloric acid (0.28 mCi/mL) into the solution and stirred it overnight before filtering it through a 0.45- μ m pore size, disposable (cellulose nitrate) membrane filter. Researches next pipetted 0.10 mL of Sr-85 in hydrochloric acid (0.28 mCi/mL) into the solution and stirred overnight followed by filtration through a 0.45- μ m pore size, disposable (cellulose nitrate) membrane filter. We stored the final solution in clean 8 L PE carboy labeled as "7.5 M Low". Personnel used distilled, deionized water to dilute the "7.5 M Low" stock solution to yield 2.75 L of "6.0 M Low" and 1.5 L of "4.5 M Low" stock.

Adsorption Tests

All tests used one of the six salt solutions prepared above, MST manufactured by Optima Chemical Company, Inc. (Batch #33180), reagent grade sodium tetraphenylborate (Aldrich, Lot # 01608AQ) and a synthetic Purex sludge prepared by M. J. Barnes (see Table II). Researchers placed 100 mL of the appropriate salt solution into a capped, high-density PE bottle and held the solution overnight at temperature (i.e., 25, 45, or 65 °C). The following day, personnel added the measured quantities of MST, NaTPB and sludge solids to the appropriate test bottle. They then capped the bottles and agitated those bottles in the Lab Line waterbath. Tests were run at the three temperatures in the following order; 25 °C, 65 °C and 45 °C. Water loss from the Lab Line waterbath during the 65 °C test required the use of a continuous slow water addition (of approximately 2 mL/min) to maintain the liquid level at or above the level in the sample bottles.

Temperature control occurred either by inserting the test bottles into a Fisher Isotemp Model # 205 waterbath (unagitated) or a Lab Line (Cole-Parmer Catalog #E-01290-20) waterbath (agitated). Figure 1 presents photographs of test bottles in the two waterbaths. Researchers selected bottle locations within the waterbath at random and changed bottle positions for each temperature.

Personnel recorded waterbath temperatures using a thermistor thermometer (Omega® Model # 5831) with thermistor probes (Omega® Model #OL-703) inserted into each waterbath. Figures 2-4 contain plots of the temperature recordings during each test period. Table III provides calculated average and mean temperatures for each test and waterbath.

Table II. Concentration of Major Metal Components in Synthetic Purex Sludge

<u>Metal</u>	<u>Wt %^a</u>
Fe	28.8
Mn	5.9
Al	4.8
Ni	2.5
Zr	2.5
Pb	0.3
Cr	0.2
Zn	0.2
Mg	0.1

^a Weight percent on dry sludge basis. Composition based on values reported in "Revision of Batch 1 Sludge Composition for Integrated Cold Run in the Defense Waste Processing Facility," N. D. Hudson, WSRC-TR-95-0079, February 16, 1995.

Table III. Average and Mean Waterbath Temperatures

<u>Target Test Temperature</u>	<u>Temperature (°C)</u>			
	<u>Isotemp</u>		<u>Lab Line</u>	
	<u>Average¹</u>	<u>Mean</u>	<u>Average¹</u>	<u>Mean</u>
25 °C	25.18 (0.25)	25.16	25.48 (0.22)	25.43
45 °C	45.41 (0.56)	45.37	45.38 (0.80)	45.66
65 °C	65.06 (0.63)	65.19	64.12 (1.33)	64.36

¹ numbers in parenthesis represent a single standard deviation

Figure 1A. Lab Line Orbital Shaker Waterbath

Front View

Top View

Figure 1B. Isotemp Waterbath

Front View

Top View

Sampling of each test bottle occurred after approximately 2, 4, 8, 24, 48, 96 and 168 hours in the tests at 45 and 65 °C tests. Collection of the samples for the 25 °C test occurred at those times as well as at 240 hours. The sampling method consisted of removing the test bottle from the waterbath, briskly shaking for about 30 seconds to provide a homogeneous suspension, and pulling approximately 5 mL of the suspension into a disposable plastic syringe. The researcher then inserted a 0.45 μ m disk (nylon membrane) filter onto the syringe, collected about 4 mL of filtrate into a clean PE sample bottle and pipetted 3 mL of the resulting filtrate into a glass vial containing 3 mL of 5M nitric acid.

Personnel discarded all excess filtrate. Personnel recapped the test bottle and returned it to the waterbath. The total time outside of the waterbath for sampling did not exceed 2 minutes. A white precipitate formed immediately upon mixing of the sample with the nitric acid. Personnel then capped the glass sample vial, gently agitated the contents, and allowed it to stand at ambient laboratory temperature until all solids dissolved.

The Analytical Development Section of SRTC performed all radiochemical analyses. Strontium-85 and neptunium-237 activity determinations occurred by gamma pulse height spectroscopy. Concentration measurements of strontium-88, neptunium-237, uranium-238, plutonium-239 and plutonium-240 measurements used ICP-MS (Inductively Coupled Plasma Mass Spectroscopy) analysis. Plutonium-239/240 activity determination relied on alpha spectroscopy after chemical separation from Np-237.

An additional set of five tests evaluated the effect of more vigorous mixing on the adsorption extent and rate. Table IV lists specific conditions for each test. The speed of the magnetic stirrer (700 rpm) provided a visible vortex and kept all of the MST solids suspended throughout the solution. A speed of 200 rpm in the orbital mixer agitated the solution, but did not suspend the majority of the MST solids.

These five tests occurred at ambient laboratory temperature. Over the course of these tests, the ambient laboratory temperature averaged 17.62 ± 0.26 °C and the water temperature in the shaking waterbath averaged 20.78 ± 0.19 °C. Sampling occurred at about 0.3, 0.5, 0.75, 1.0, 1.5, 2.0, 4.0, 7.0 and 24 hours. The authors decided to sample earlier and more frequently in these tests based on the test results from the above experimental design.

Table IV. Test Conditions in Additional Mixing Tests

<u>Test #</u>	<u>Mixing Type</u> ^a	<u>Speed (rpm)</u>	<u>Solution</u> ^b	<u>[MST] (g/L)</u>
M1	magnetic	700	4.5M Hi	1.74
O1	orbital	200	4.5M Hi	1.56
M3	magnetic	700	4.5M Lo	0.0
M4	magnetic	700	4.5M Lo	1.75
O2	orbital	200	4.5M Lo	3.51

^a magnetic = Barnstead/Thermolyne (Model SP73235) 4-place magnetic stirrer

orbital = Lab Line (Cole-Parmer Catalog #E-01290-20) shaking waterbath

^b 4.5M Hi represents the high activity 4.5M Na⁺ M salt solution

4.5M Lo represents the low activity 4.5M Na⁺ M salt solution

Figure 2. Waterbath Temperature Profiles at 25 °C **Figure 3. Waterbath Temperature Profiles at 45 °C**

Figure 4. Waterbath Temperature Profiles at 65 °C

Results and Discussion

Experimental Design

The statistically designed set of tests included the following parameters: temperature, sodium ion concentration, MST concentration, initial concentrations (of strontium, neptunium, uranium and plutonium), mixing, and the presence of sodium tetraphenylborate and sludge solids. Table V provides a list of the targeted range of values for each parameter. The target sorbate concentrations were selected based on solubility considerations (i.e., the high value is at or near the solubility limit for the sorbate). For strontium and neptunium, the solubility limits are much greater than expected concentrations in the feed solutions to the salt processing facility [11]. Because of the high neptunium and uranium concentrations, the upper MST concentration was set at 2.0 g/L.

The initial strontium and plutonium concentrations were significantly lower than the target values. Total strontium concentration initiated at about 0.006 mg/L for the low activity solutions and about 0.080 mg/L for the high activity solutions. Total plutonium concentration initiated from about 0.001 to 0.006 mg/L for the low activity solutions and about 0.2 mg/L for the high activity solutions. Appendices 1-3 provide the initial concentrations for each test.

Table V. Targeted Parameter Values

<u>Parameter</u>	<u>Targeted Experimental Range</u>		
	<u>Low</u>	<u>Mid</u>	<u>High</u>
Temperature	25 °C	45 °C	65 °C
Sodium Concentration	4.5 M	6.0 M	7.5 M
MST Concentration ¹	0.2 g/L	1.1 g/L	2.0 g/L
Mixing	no		yes
Strontium	0.1 mg/L		1.0 mg/L
Neptunium	4.0 mg/L		40 mg/L
Uranium	1.0 mg/L		10 mg/L
Plutonium	0.1 mg/L		1.0 mg/L
Sodium Tetrphenylborate	0.0 mg/L		400 mg/L
Sludge Solids	0.0 mg/L		400 mg/L

¹ test with MST concentration of 0.0 g/L also included as a baseline to correct for precipitation or sorption of the radionuclides onto testing equipment.

Table VI provides an outline of the statistical experimental design. The table differs from that originally developed to reflect a lower temperature [4]. Due to constraints on the number of bottles that can fit in the agitated waterbath, researchers did not replicate the tests with sludge and NaTPB solids.

Table VI. Statistical Design Test Outline

Experimental Notes	Actinide (Pu, U, and Np) and Sr Loading												Rep
	Low						High						
	Temp °C	MST g/L	Na+ M	Mixing	TPB	Sludge	Temp °C	MST g/L	Na+ M	Mixing	TPB	Sludge	
Baseline	25	0	6	Yes	No	No	25	0	6	Yes	No	No	Yes
Special	25	1.1	6	Yes	Yes	No	25	1.1	6	Yes	Yes	No	No
	25	1.1	6	Yes	No	Yes	25	1.1	6	Yes	No	Yes	No
Designed	25	1.1	6	No	No	No	25	1.1	6	No	No	No	Yes
	25	1.1	6	Yes	No	No	25	1.1	6	Yes	No	No	Yes
	25	0.2	4.5	Yes	No	No	25	0.2	4.5	Yes	No	No	Yes
	25	0.2	7.5	Yes	No	No	25	0.2	7.5	Yes	No	No	Yes
	25	1	4.5	Yes	No	No	25	1	4.5	Yes	No	No	Yes
	25	1	7.5	Yes	No	No	25	1	7.5	Yes	No	No	Yes
Baseline	70	0	6	Yes	No	No	70	0	6	Yes	No	No	Yes
	70	1.1	6	Yes	Yes	No	70	1.1	6	Yes	Yes	No	No
Special	70	1.1	6	Yes	No	Yes	70	1.1	6	Yes	No	Yes	No
	70	1.1	6	No	No	No	70	1.1	6	No	No	No	Yes
	70	1.1	6	Yes	No	No	70	1.1	6	Yes	No	No	Yes
	70	0.2	4.5	Yes	No	No	70	0.2	4.5	Yes	No	No	Yes
	70	0.2	7.5	Yes	No	No	70	0.2	7.5	Yes	No	No	Yes
	70	2	4.5	Yes	No	No	70	2	4.5	Yes	No	No	Yes
	70	2	7.5	Yes	No	No	70	2	7.5	Yes	No	No	Yes
Baseline	45	0	6	Yes	No	No	45	0	6	Yes	No	No	Yes
	45	1.1	6	Yes	Yes	No	45	1.1	6	Yes	Yes	No	No
Special	45	1.1	6	Yes	No	Yes	45	1.1	6	Yes	No	Yes	No
	45	1.1	6	No	No	No	45	1.1	6	No	No	No	Yes
	45	0.2	6	Yes	No	No	45	0.2	6	Yes	No	No	No
	45	2	6	Yes	No	No	45	2	6	Yes	No	No	No
	45	1.1	4.5	Yes	No	No	45	1.1	4.5	Yes	No	No	No
	45	1.1	7.5	Yes	No	No	45	1.1	7.5	Yes	No	No	No
	45	1.1	6	Yes	No	No	45	1.1	6	Yes	No	No	No
	45	1.1	6	Yes	No	No	45	1.1	6	Yes	No	No	No
	45	1.1	6	Yes	No	No	45	1.1	6	Yes	No	No	No
	45	1.1	6	Yes	No	No	45	1.1	6	Yes	No	No	No
	45	1.1	6	Yes	No	No	45	1.1	6	Yes	No	No	No
	45	1.1	6	Yes	No	No	45	1.1	6	Yes	No	No	No
	45	1.1	6	Yes	No	No	45	1.1	6	Yes	No	No	No
45	1.1	6	Yes	No	No	45	1.1	6	Yes	No	No	No	

REP = Replicated test

Control Samples

Each test set consisted of two bottles containing the low activity and two bottles containing the high activity 6.0 M Na⁺ salt solutions with no added MST. These tests serve as control samples to correct for removal of sorbates by sorption onto the bottle walls, the filter or by precipitation. Appendix 1 provides the average sorbate concentration versus time data at each temperature for the control samples. Appendices 2-5 show plots of the concentration versus time data for each sorbate and temperature.

The high activity solutions exhibited relative standard deviations of the sorbate concentrations with time of less than 10% and, therefore, were not corrected. The low activity solutions exhibited relative standard deviations of greater than 10% in the strontium, plutonium and neptunium concentrations. Correction factors consisted of the ratio of the initial concentration to that at the time of sampling. These correction factors were applied to the other concentration results for tests with added MST. As a result of this correction factor, some graphs of the sorbate concentration versus time exhibit an

initial decrease and then an increase in the sorbate concentration. This occurs more often when the measured concentration approaches the analytical detection limit of the sorbate.

Removal Efficiency Criteria

The appropriate isotopic limit for decontaminated salt solution sent to Z-Area provides the criteria for removal of each radionuclide [5]. Uranium does not have a criterion since the combination of the low specific activity and low solubility of uranium prohibits the decontaminated salt solution from exceeding the total alpha activity of 20 nCi/g. For example, the calculated alpha activity for uranium assuming 100% U-235 (highest specific activity) is 0.046 nCi/g at the highest uranium concentration tested (26 mg/L). The neptunium-237 limit is 0.03 nCi/g which equals 51 - 56 µg/L for salt solutions ranging in density from 1.206 (4.5 M Na⁺) to 1.336 g/mL (7.5 M Na⁺).

The Sr-90 limit for feed solution to Z-Area is 40 nCi/g [5]. To convert the activity limit to a total strontium mass concentration basis, we set the Sr-90 content at either 45 or 5.2 atomic (at) %. The higher value derives from the known fission yields of Sr-88 and Sr-90 [6] and correcting for radioactive decay of the Sr-90 (assuming an average waste age of 29 years). The lower value equals that determined in a sample of Tank 51H sludge analyzed at SRTC [7]. The 45 at % value provides a reasonable upper limit for Sr-90 since impurities in processing chemicals and process water add some amount of non-radioactive strontium into the HLW. This value is not necessarily bounding since the age of the waste processed could be less than 29 years. Table VII provides a list of the strontium limits based on mass concentration.

Table VII. Sr-90 Limits Converted to Total Strontium Mass Limits

<u>Atomic % Sr-90</u>	<u>Concentration Limit (µg/L)</u>	
	<u>@ 4.5 M Na⁺</u>	<u>@ 7.5 M Na⁺</u>
5.2	6.5	7.3
45	0.76	0.84

Plutonium-containing wastes originate from the production of weapons grade (WG) plutonium (containing primarily Pu-239/240) and heat source (HS) plutonium (containing primarily Pu-238). Z-Area limits the total alpha activity in decontaminated salt solution to 20 nCi/g [5]. We converted this limit to a mass concentration assuming all of the alpha activity comes from plutonium and that the plutonium has either a WG or HS isotopic distribution [9,10]. The resulting mass limit for HS plutonium (1.6-1.8 µg/L) proves much lower than that for WG plutonium (40-44 µg/L) due to the much higher specific activity for HS Pu (14.6 Ci/g) compared to WG plutonium (0.60 Ci/g). Table VIII provides the Z-Area limits on a mass concentration basis for the 4.5 M and 7.5 M salt solutions.

Table VIII. Plutonium Mass Concentration Limits

<u>Isotopic Distribution</u>	<u>Concentration Limit ($\mu\text{g/L}$)</u>	
	<u>@ 4.5 M Na^+</u>	<u>@ 7.5 M Na^+</u>
Weapons Grade Pu	40	44
Heat Source Pu	1.6	1.8

Extent of Strontium Removal

Plots of strontium concentration versus time exhibit the expected decrease in concentration with increasing time. After a period of time, no further change occurred in the solution concentration indicating the system had attained equilibrium. Figures 5 - 8 provide graphs of the strontium concentration versus time at each temperature, at each initial concentration, at the bounding ionic strength concentrations (4.5 and 7.5 M Na^+) and at the lowest MST concentration (0.2 g/L). This MST concentration represents the planned average concentration in each of the salt disposition flowsheets [12]. Appendices 9 - 22 provide the strontium concentration data for all test conditions including higher sodium ion concentrations and MST concentrations.

The equilibrium strontium concentration was below strontium mass limits for the range of feed isotopics (e.g., 5.2 – 45 at %) considered at each temperature and initial strontium concentration for the lower ionic strength solution (Figures 5 and 6). For the higher ionic strength solutions, the final strontium concentration fell below the limit assuming 5.2 at % Sr-90 in the feed, but failed to meet the limit assuming 45 at % Sr-90 in the feed (Figures 7 and 8). Thus, concentrated salt solutions having 45 atomic % Sr-90 need more than 0.2 g/L of MST to reach the Sr-90 limit.

Figure 5. Strontium Removal – 4.5 M Na^+ , Low Activity, 0.2 g/L MST

Figure 6. Strontium Removal – 4.5 M Na⁺, High Activity, 0.2 g/L MST **Figure 7. Strontium Removal – 7.5 M Na⁺, Low Activity, 0.2 g/L MST**

Figure 8. Strontium Removal – 7.5 M Na⁺, High Activity, 0.2 g/L MST Extent of Plutonium Removal

Assuming WG isotopics for the feed, the final plutonium concentration fell below the limit at each temperature, initial plutonium concentration and each ionic strength (Figures 9 - 12). Appendices 9 - 22 provide the plutonium concentration data for all test conditions including higher sodium ion concentrations and MST concentrations. For feed containing HS plutonium, the final plutonium concentration in solution met the limit for the lower activity solution (Figure 9) and approached the limit for the higher activity solution (Figure 10). The plutonium concentrations in the higher activity solution reached the lower limit of detection of the analytical method, which nearly equals the mass limit for feed containing HS plutonium. Thus, one cannot conclusively determine if the higher activity solution satisfies the limit with this data. For the high ionic strength feed solution containing HS plutonium, the only test in which the final plutonium concentration did not satisfy the limit was the low activity solution at 65 °C (Figure 11). Thus, we conclude that the facility would need to control the temperature to lower values or use higher MST concentrations to remove sufficient HS plutonium from solution if present initially at or near the solubility limit for plutonium.

Figure 9. Plutonium Removal - 4.5 M Na⁺, Low Activity, 0.2 g/L MST **Figure 10. Plutonium Removal - 4.5 M Na⁺, High Activity, 0.2 g/L MST**

Figure 11. Plutonium Removal - 7.5 M Na⁺, Low Activity, 0.2 g/L MST **Figure 12. Plutonium Removal - 7.5 M Na⁺, High Activity, 0.2 g/L MST**

Extent of Uranium Removal

Figures 13 - 16 provide the graphs of uranium concentrations versus time for the two levels of sodium ion and initial uranium concentrations at a MST concentration of 0.2 g/L. Appendices 9 - 22 provide the uranium concentration data for all test conditions including tests at higher sodium ion concentrations and MST concentrations. Table IX provides a summary of the average equilibrium uranium decontamination factor at each temperature for the various test conditions. The decontamination factor is the ratio of the initial concentration to the equilibrium concentration.

Decontamination factors (DF) remained below 3 (<67% removal) for all solutions treated with 0.2 g/L MST. Greater than 93% removal of uranium occurred in the low activity solutions when the MST concentration increased to ≥ 1.1 g/L. Uranium removal remained fairly low for all of the high activity solutions and MST concentrations. An increase in the MST concentration by a factor of 10 did not result in a similar increase in the DF. This result suggests that other sorbates are successfully competing with uranium for MST sites.

Table IX. Average Equilibrium Uranium Decontamination Factors

Test Conditions				Average Decontamination Factor		
[Na ⁺]	[MST]	Solution	Other	25 °C	45 °C	65 °C
4.5	0.2	low	mixed	2.48	2.59	2.56
4.5	2.0	low	mixed	≥ 131	≥ 138	> 690
6.0	1.1	low	mixed	24.4	22.9	15.9
6.0	1.1	low	unmixed	21.8	10.0	17.9
6.0	1.1	low	NaTPB	23.0	20.6	15.1
6.0	1.1	low	sludge	24.0	19.4	24.6
7.5	0.2	low	mixed	1.39	1.68	1.74
7.5	2.0	low	mixed	17.3	27.4	21.1
4.5	0.2	high	mixed	1.24	1.25	1.36
4.5	2.0	high	mixed	7.83	13.0	9.94
6.0	1.1	high	mixed	2.74	2.94	2.83
6.0	1.1	high	unmixed	2.45	2.80	2.73
6.0	1.1	high	NaTPB	2.71	2.76	2.90
6.0	1.1	high	sludge	2.15	2.43	2.34
7.5	0.2	high	mixed	1.72	1.53	1.58
7.5	2.0	high	mixed	5.06	6.54	4.48

Figure 13. Uranium Removal - 4.5 M Na⁺, Low Activity, 0.2 g/L MST **Figure 14. Uranium Removal - 4.5 M Na⁺, High Activity, 0.2 g/L MST**

Figure 15. Uranium Removal - 7.5 M Na⁺, Low Activity, 0.2 g/L MST **Figure 16. Uranium Removal - 7.5 M Na⁺, High Activity, 0.2 g/L MST**

Extent of Neptunium Removal

Figures 17 – 20 present plots of the neptunium-237 concentration versus time for the low and high activity and 4.5 M and 7.5 M sodium ion solutions at each of the three temperatures and 0.2 g/L MST. Appendices 9 – 22 provide the neptunium concentration data for all test conditions including the higher sodium ion concentrations and MST concentrations. The final neptunium-237 concentration exceeded the Z-Area limit in all of the high activity solution tests. The final neptunium-237 concentration was within the Z-Area limit for the low activity salt solutions at all temperatures for the low (4.5 M) and intermediate (6.0 M) sodium ion concentrations. At the high (7.5 M) sodium ion concentration, the final neptunium-237 concentration was within the Z-Area limit only at 45 and 65 °C and 2.0 g/L MST (Figures 13 and 14).

Comparison of Figure 17 (4.5 M Na⁺, low activity, 0.2 g/L MST) and Figure 19 (7.5 M Na⁺, low activity, 0.2 g/L MST) indicates that the Np-237 concentration will be within the limit for feed solution to Z-Area by treating with 0.2 g/L MST if the initial concentration of Np-237 is no more than 0.6 mg/L and the ionic strength does not exceed 4.5 M Na⁺. At initial Np-237 concentrations above 0.6 mg/L, 0.2 g/L MST is insufficient to remove enough neptunium to be within the limit. Figure 19 shows this trend. Note that decontamination factors (C_0/C) increased with increased temperature in tests with 4.5 M Na⁺ solutions, but not in tests with 7.5 M Na⁺ solutions.

J. Fowler reported a predicted maximum concentration of neptunium-237 in waste tank of 500 µg/L [11], slightly higher than the low ionic strength/low activity solution case (340 µg/L) in these tests. Fowler shows an estimated initial uranium concentration for the projected case of 1.5 mg/L, well below the solubility limit (about 10 mg/L) used in the current testing. Thus, we recommend additional tests at 0.5 mg/L Np-237 and 10 mg/L uranium to determine whether the process can satisfy the neptunium limit at MST concentrations of 0.2 and 0.4 g/L.

Given the high neptunium and uranium concentrations and the relatively low MST concentration, we expected tests at 0.2 g/L MST to severely stress the ability to meet the facility requirements. Unexpectedly, tests at 1.1 and 2.0 g/L MST with the high activity solutions did not remove sufficient neptunium-237 to achieve final concentration below the Z-Area limit.

Calculations indicate that the mole ratio of all sorbates to MST is below 0.01 for the high activity solutions at MST concentrations ≥ 1.1 g/L (see Appendix 24). At this low mole ratio, sufficient sites should be available to remove a large fraction of the neptunium and uranium. Final neptunium-237 and uranium concentrations in the high activity solutions with 1.1 and 2.0 g/L MST (Appendices 18, 19, 20, 21 & 23) indicate greater neptunium removal with increasing temperature. In contrast, uranium removal does not exhibit the same behavior with temperature. We attribute these results to either a different mechanism for removal for neptunium at the higher temperatures (e.g., surface precipitation) or more rapid adsorption kinetics compared to uranium.

Figure 17. Neptunium Removal - 4.5 M Na⁺, Low Activity, 0.2 g/L MST **Figure 18. Neptunium Removal - 4.5 M Na⁺, High Activity, 0.2 g/L MST**

Figure 19. Neptunium Removal - 7.5 M Na⁺, Low Activity, 0.2 g/L MST Figure 20. Neptunium Removal - 7.5 M Na⁺, High Activity, 0.2 g/L MST

Equilibrium Distribution Constants

The equilibrium distribution constant, K_d , generally serves as the term used to evaluate the extent of removal in batch tests. One defines K_d as the ratio of the concentration of the sorbate on the MST to the equilibrium sorbate concentration in solution (equation 1) with units of mL/g.

$$K_d = \{M\}_s / [M]_{aq}^e = (([M]_{aq}^o / [M]_{aq}^e) - 1) / [MST] \quad (1)$$

where, $\{M\}_s$ equals the equilibrium concentration of sorbate, M, on the MST sorbent in mmol/g, $[M]_{aq}^e$ equals the equilibrium concentration of sorbate, M, in solution in units of mmol/mL, $[M]_{aq}^o$ equals the initial concentration of sorbate, M, in solution in units of mmol/mL, and $[MST]$ equals the concentration of MST in g/mL.

Appendices 5 - 7 provide the calculated K_d values for each test. In some cases, the Appendix reports a K_d as greater than a given value. This occurs when the equilibrium solution concentration of the sorbate falls below the detection limit of the analytical method.

As anticipated, strontium exhibited the highest K_d values followed by plutonium. Neptunium and uranium exhibited similar K_d values, with both much lower than those for strontium and plutonium. Although neptunium and uranium exhibited lower K_d values, the MST adsorbs more neptunium and uranium on a mass basis than strontium and plutonium. The higher mass loading reflects the much higher mass concentrations of neptunium and uranium compared to strontium and plutonium (see Table V and Appendices 5 - 7).

Models for Predicting Equilibrium Sorbate Concentrations

Statistical analysis of the equilibrium concentrations for each of the sorbates values using JMP® Version 3.2.2, a commercial software package from SAS Institute, Inc. identified which of the testing parameters significantly affected the equilibrium concentrations. The equilibrium concentration is modeled as a linear function of the independent parameters as shown in equation (2)

$$[S]_e = a + b f(x) + c f(y) + d f(z) \quad (2)$$

where, $[S]_e$ is the equilibrium sorbate concentration

a, b, c and d are constants

$f(x)$, $f(y)$ and $f(z)$ are some functional form of the independent parameter.

The functional form of the parameter can be the parameter, a mathematical function of the parameter (e.g., $\ln[Sr]_o$) or a product of parameters (e.g., $[Sr]_o \times [MST]$ or $[Sr]_o \times [Sr]_o$). Initially, modeling included all of the test results. Upon further review, the analysis was divided into 3 subsets: (1) trials varying initial sorbate concentration, temperature, MST concentration and ionic strength (standard trials), (2) trials at constant ionic strength and MST concentration with and without mixing (mixing trials) and (3) trials at constant ionic strength and MST concentration with and without the addition of NaTPB and sludge solids (spiked trials).

Effects of Mixing and Addition of NaTPB and Sludge Solids

Results from the analysis of the latter two subsets indicated the following: (1) mixing is statistically significant for the determination of the final strontium and plutonium concentrations but not uranium and neptunium concentrations, (2) addition of sludge is statistically significant for the determination of final strontium, plutonium and uranium concentrations and (3) addition of NaTPB is not statistically significant for the determination of any final sorbate concentrations. Table X provides a summary of the parameters, parameter coefficients and significance levels for the mixing and spiked trials. Appendices 25 and 26 provide details of these statistical evaluations. Mixing could affect rate of sorption, but should not affect equilibrium sorbate concentrations. We believe the results obtained above for mixing indicates that the system may not be at true equilibrium at the time of the final sampling. Alternatively, mixing could be deagglomerating the MST making more sites available for sorption resulting in lower final sorbate concentrations.

Table X. Summary of Statistical Model Parameters for Mixing and Spiked Trials

Mixing Trials								
	Strontium		Plutonium		Uranium		Neptunium	
	<u>Response</u>	<u>SL</u>	<u>Response</u>	<u>SL</u>	<u>Response</u>	<u>SL</u>	<u>Response</u>	<u>SL</u>
r^2	0.783	-	0.987	-	0.994	-	0.995	-
intercept	0.0162	0.268	0.635	<0.0001	9960	0.021	-4910	0.0005
mixing	0.00847	0.0059	0.0278	0.0129	111	0.121	148	0.2226
T	0.00164	<0.0001	-0.0073	<0.0001	178	0.141	55.7	0.0002
T x T					-2.10	0.140		
$[S]^0$	-0.00206	0.0746	0.0019	<0.0001	-6.85	0.040	3.75	<0.0001
$[S]^0 \times [S]^0$	0.00003	0.0120			0.00035	0.029	-0.000094	0.0017
T x $[S]^0$			0.00038	<0.0001	-0.00951	0.011		
Spiked Trials								
	Strontium		Plutonium		Uranium		Neptunium	
	<u>Response</u>	<u>SL</u>	<u>Response</u>	<u>SL</u>	<u>Response</u>	<u>SL</u>	<u>Response</u>	<u>SL</u>
r^2	0.824	-	0.984	-	0.989	-	0.980	-
intercept	0.0756	0.110	0.223	<0.0001	2710	0.272	-4980	0.0310
NaTPB	0.00481	0.482	0.0118	0.572	-264	0.102	-192	0.574
Sludge	0.0197	0.0090	-0.0527	0.0193	490	0.0052	47.3	0.890
T	-0.00303	0.165	-0.00166	0.0597	0.836	0.933	55.3	0.0587
T x T	0.000065	0.0111						
$[S]^0$	0.00124	0.0015	0.0143	0.0011	-1.33	0.272	3.74	0.0138
$[S]^0 \times [S]^0$			-0.000047	0.0122	0.0000856	0.1432	-0.000098	0.0530
T x $[S]^0$	0.00003	0.0120			-0.00313	0.0427	-0.0123	<0.0001

Response is the value of the parameter coefficient

SL = Significance Level (a value of ≤ 0.05 is considered statistically significant).

r^2 = Correlation coefficient, T = temperature ($^{\circ}\text{C}$), $[S]^0$ = initial sorbate concentration in $\mu\text{g/L}$.

Additional tests provided additional insight into the effects of mixing on sorbate removal (see Table IV in Experimental Section). These tests utilized the low and high activity 4.5 M Na^+ solutions under well stirred (magnetic) and gently agitated (orbital) conditions. Figures 21 - 23 present graphs of strontium, plutonium and neptunium concentrations, respectively, versus time for both the low

activity and high activity solutions. Initial concentrations are omitted from the graphs to allow plotting both axes on a logarithmic scale.

For the high activity solutions, there is no difference in the rate of removal for any of the three sorbates. The extent of removal is higher for the magnetically stirred test. We attribute this result to the slightly higher MST concentration in the magnetically stirred test (1.75 g/L) compared to the orbital shaken test (1.56 g/L).

For the low activity solution, the rate of strontium removal is similar for both mixing types as evidenced by similar slopes. The orbital shaker achieves equilibrium more quickly due to the higher MST concentration (3.51 g/L vs. 1.75 g/L). Results after about 1 hour into the test have high experimental uncertainties from the counting statistics. Longer counting times would decrease this uncertainty. However, due to large differences in MST concentrations and additional costs, we chose not to perform longer counting times for this test set.

Figure 21. Affect of Mixing on Strontium Removal

Figure 22. Affect of Mixing on Plutonium Removal **Figure 23. Affect of Mixing on Neptunium Removal**

Analysis of the tests indicated that the equilibrium concentration of strontium, plutonium and uranium is affected by the addition of 400 mg/L of synthetic Purex sludge. Adsorption of plutonium and uranium species by hydrous iron oxides under alkaline conditions has been previously reported [14,15]. The correlation coefficients of the fitted model are 0.824 for strontium, 0.984 for plutonium and 0.990 for uranium. The lower correlation coefficient for strontium indicates a poorer fit of the data.

When compared to other parameters (e.g., initial sorbate concentration, MST concentration, ionic strength, etc.), the effect of sludge solids on equilibrium sorbate concentration is small (e.g., compare predictive equations between special spiked trials to those in the standard trials). During HLW processing, supernate and some amount of sludge solids will pass into the salt processing facility. The sludge solids will have been in contact with the waste solution and thus be at or near equilibrium with respect to adsorption of solution phase species. Mixing two different waste materials would change the equilibrium, but would not result in complete desorption of species from the sludge solids. Thus, the likelihood is extremely low that any sludge solids could enter into the supernate processing facility without previously adsorbed strontium, plutonium and uranium. Therefore, we conclude that the impact of sludge solids is negligible in considering the rate and extent of strontium, plutonium, uranium and neptunium removal with MST.

Equilibrium Sorbate Concentrations

Predictive models were developed from the results of the standard trials in which the concentrations of the sorbates, MST and sodium ion concentration (ionic strength or Z) and the temperature were varied. Appendices 25 -28 provide details of the fitted models. The upper and lower 95% confidence intervals are much narrower for strontium, uranium and neptunium compared to plutonium. For example the predicted values for the upper and lower 95% confidence interval for a single predicted condition vary by about $\pm 20\%$ from the average value for strontium, uranium and neptunium. For plutonium the range varies by about $\pm 100\%$. The wide confidence intervals do not result from replicate variability, which proved small in most tests. We attribute the model uncertainty to one or more unidentified parameters, parameter interactions confounded with main factors, and to the difficulty imposed by the analytical detection limit in many experiments particularly with plutonium measurements.

Equilibrium Strontium Concentration

Statistically significant parameters affecting strontium removal include temperature, ionic strength and the initial strontium concentration. The analysis provided the following predictive equation for equilibrium strontium concentration:

$$\begin{aligned}
 [\text{Sr}]^{\text{e}}_{\text{aq}} = & 4.343 + 1.022 * [\text{MST}] + 0.00574 * T - 1.68 * Z - 0.00314 * [\text{Sr}]^{\text{o}}_{\text{aq}} \quad (2) \\
 & - 0.181 * Z * [\text{MST}] + 0.159 * Z^2 + 0.000116 * \{[\text{Sr}]^{\text{o}}_{\text{aq}}\}^2 \\
 & - 0.00119 * Z * [\text{Sr}]^{\text{o}}_{\text{aq}} - 0.00164 * [\text{MST}] * [\text{Sr}]^{\text{o}}_{\text{aq}} + 0.0000832 * T * [\text{Sr}]^{\text{o}}_{\text{aq}} \\
 & - 0.00494 * T * [\text{MST}]
 \end{aligned}$$

where T = Temperature ($^{\circ}\text{C}$), Z = ionic strength (M) and $[\text{Sr}]^{\text{o}}_{\text{aq}}$ = the initial strontium concentration ($\mu\text{g/L}$). The correlation coefficient for the fitted model is 0.972.

Equilibrium Plutonium Concentration

Statistically significant parameters affecting the equilibrium plutonium concentration include MST concentration, ionic strength, temperature, the initial plutonium concentration and cross terms including all of the previous parameters. The analysis gave the following predictive equation for the equilibrium plutonium concentration:

$$\begin{aligned}
 [\text{Pu}]_{\text{aq}}^{\text{e}} = & 7.40 + 0.276*[\text{MST}] - 2.13*Z - 0.0536*T + 0.0187*[\text{Pu}]_{\text{aq}}^{\text{o}} \quad (3) \\
 & + 0.0196*[\text{MST}]*T - 0.0302*[\text{MST}]*Z + 0.294*Z^2 + 0.00131*T^2 \\
 & - 0.00046*\{[\text{Pu}]_{\text{aq}}^{\text{o}}\}^2 + 0.004413*[\text{MST}]*[\text{Pu}]_{\text{aq}}^{\text{o}} - 0.0192*T*Z \\
 & + 0.0122*Z*[\text{Pu}]_{\text{aq}}^{\text{o}}
 \end{aligned}$$

The correlation coefficient for the fitted model is 0.789. The lack of fit is poorer for plutonium than the other sorbates. We attribute the poorer fit to the high number of equilibrium concentrations (30 out of 60 tests) which were below the analytical detection limit.

Equilibrium Uranium Concentration

Statistically significant parameters affecting the equilibrium uranium concentration include MST concentration, ionic strength, initial uranium concentration and cross terms including these parameters. The analysis yielded the following predictive equation for the equilibrium uranium concentration:

$$\begin{aligned}
 [\text{U}]_{\text{aq}}^{\text{e}} = & 15480 - 2480*[\text{MST}] - 4650*Z + 0.824*[\text{U}]_{\text{aq}}^{\text{o}} + 349*[\text{MST}]*Z \quad (5) \\
 & + 329*Z^2 - 0.27*[\text{MST}]*[\text{U}]_{\text{aq}}^{\text{o}} - 0.0137*Z*[\text{U}]_{\text{aq}}^{\text{o}}.
 \end{aligned}$$

where $[\text{MST}]$ = MST concentration (g/L), Z = ionic strength (M), $[\text{U}]_{\text{aq}}^{\text{o}}$ = the initial uranium concentration ($\mu\text{g/L}$) and T = Temperature ($^{\circ}\text{C}$). The correlation coefficient for the fitted model is 0.979.

Equilibrium Neptunium Concentration

Statistically significant parameters affecting the equilibrium neptunium concentration include MST concentration, ionic strength, temperature and cross terms including these parameters and the initial neptunium concentration. The analysis resulted in the following predictive equation for the equilibrium neptunium concentration:

$$\begin{aligned}
 [\text{Np}]_{\text{aq}}^{\text{e}} = & 2140 - 240*[\text{MST}] - 652*Z - 12.6*T + 0.967*[\text{Np}]_{\text{aq}}^{\text{o}} \quad (5) \\
 & - 31.1*[\text{MST}]*T + 238*[\text{MST}]*Z + 8.55*Z*T \\
 & - 0.116*[\text{MST}]*[\text{Np}]_{\text{aq}}^{\text{o}} - 0.0103*T*[\text{Np}]_{\text{aq}}^{\text{o}}.
 \end{aligned}$$

where T = Temperature ($^{\circ}\text{C}$), Z = ionic strength (M), $[\text{MST}]$ = concentration of monosodium titanate and $[\text{Np}]_{\text{aq}}^{\text{o}}$ = the initial neptunium-237 concentration ($\mu\text{g/L}$). The correlation coefficient for the fitted model is 0.978.

Removal Rates

None of the test data fit first-order or second-order kinetic expressions. Previously, we reported the time to reach equilibrium or the time at which a sharp decrease in the slope of the activity-

concentration curve occurred as the primary measure for reaction rate at 25 °C [13]. Analysis of the 25 °C along with the results obtained from the tests at 45 and 65 °C did not produce a model with high correlation coefficients.

Beck et al. showed that the more important measure for sizing and establishing the residence time for the continuous stirred tank reactor (CSTR) in the Small Tank Tetraphenylborate process involves the rate at the time when the sorbate concentration passes through the required Z-Area limit [12]. The effective sodium ion concentration in the CSTR will average 4.7 M, just slightly higher than the low sodium ion concentration (4.5 M) solution tested in this study. The proposed process will use a target MST concentration in the CSTR of 0.2 g/L. Thus, we calculated the rates at a MST concentration of 0.2 g/L for those tests that satisfied the Z-Area limit for a specific sorbate. Tables XI, XII and XIII present those rates for strontium, plutonium and neptunium, respectively, determined from the tests at the minimum (4.9 M) and maximum ionic strengths (8.2 M) (i.e., 4.5 M Na⁺ and 7.5 M Na⁺).

For the 4.5 M Na⁺ solutions, the strontium concentration passed below both Sr-90 limits (6.5 and 0.76 µg/L total Sr) (see Figures 5 and 6) even though the initial strontium concentrations differed by about a factor of 10 - 12. Incremental rates for strontium in the 4.5 M Na⁺ solutions ranged from 0.27 to 1.94 µg/L-h (see Table XI). As seen in Table XI, the strontium concentration achieved the 5.2 at % Sr-90 limit (7.3 µg/L total Sr), but did not achieve the 45 at % Sr-90 limit (0.84 µg/L total Sr). Thus, the incremental rate reported in Table XI for the 7.5 M Na⁺ solutions is that based on 5.2 at % Sr-90.

Strontium removal rates increased upon an increase in the initial strontium concentration (compare low and high activity rates for 4.5 M and 7.5 M Na⁺ solutions in Table XI). Note that the increase in removal rates between the low and high activity solutions is much greater for the lower sodium ion concentration. We attribute the smaller change in removal rates at the higher sodium ion concentration (7.5 M) to increased competition from sodium ions for adsorption sites on the MST (i.e., decreased chemical potential at higher Na⁺ concentrations).

The strontium removal rate for the 4.5 M low activity solution at 25 °C proved much lower than those measured at 45 and 65 °C (see Table XI). Rates at the higher activity solution (4.5 M Na⁺) and higher sodium ion concentrations (both low and high activity) exhibited no significant temperature effect. We attribute the large difference in incremental rates for the low-activity 4.5M Na⁺ solutions in part to the wide sampling intervals during the initial stage of the test. The first three samples were taken at about 2, 4 and 8 hours. The strontium concentration reached the limit within 2 hours at 45 and 65 °C, but just missed at 25 °C. After 4 hours, the strontium concentration was below the limit at 25 °C. Thus, the incremental rate for the 25°C test used the 2-4 hour interval, which includes a much smaller change in the strontium concentration than during the first 2 hour interval. We recommend conducting tests with more frequent sampling at the beginning of the test to provide a more accurate determination of strontium removal rates.

Table XI. Incremental Removal Rates for Strontium Upon Reaching Sr-90 Limit for Feed of Decontaminated Salt Solution to Z-Area

Temp. (°C)	Incremental Rate (µg/L-h) ^a			
	4.5 M Na ⁺ (45 at % Sr-90)		7.5 M Na ⁺ (5.2 at % Sr-90)	
	Low Activity	High Activity	Low Activity	High Activity
25	0.27	30.6	1.91	5.18
45	1.89	21.3	2.08	3.75
65	1.94	26.7	2.62	4.55

^a incremental rate determined for the time period during which the strontium concentration passed through the Z-Area Sr-90 limit for decontaminated salt solution. Both low activity and high activity solutions at low ionic strength (4.5 M Na⁺, density = 1.206 g/mL) passed through Sr-90 limits calculated based on a Sr-90 content of 5.2 at % (6.5 µg/L) and 45 at % (0.76 µg/L). At the high ionic strength (7.5 M Na⁺, density = 1.336 g/mL), the low and high activity solutions passed through the Sr-90 limit based on 5.2 at % (7.3 µg/L), but not at 45 at % (0.84 µg/L).

The initial plutonium concentrations in the low activity solutions for both the 4.5 M (Figure 9) and 7.5 M (Figure 11) Na⁺ solutions are below both the WG and HS mass limits and, therefore, one cannot calculate incremental rates for these tests. For the high activity solutions, the plutonium concentration decreased below the WG limit (Figures 10 and 12). The HS limit nearly equals the lower detection limit of the ICP-MS analytical method and, thus, we could not reliably determine an incremental rate at the HS limit.

Based on the WG incremental rates, increasing temperature appears to increase plutonium removal rates (see Table XII). Generally, the plutonium concentration fell below the limit within about 4 hours during these tests indicating fairly rapid adsorption rates. These rates may be conservatively low as the sampling interval was large during which the limit was reached. More frequent sampling as carried out in the later mixing tests indicated that the removal of plutonium reached equilibrium within 60 minutes (see Figure 22). The more recent tests occurred at a much higher MST concentration compared to the earlier tests and, thus, the rates cannot be compared directly with those reported in Table XII. The authors recommend additional tests at lower MST concentrations with more frequent sampling to provide more data points about the point where the plutonium concentration reaches the Z-Area limit.

Table XII. Incremental Removal Rates for Plutonium Upon Reaching Total Alpha Limit for Feed of Decontaminated Salt Solution to Z-Area

Temperature (°C)	Incremental Rate (µg/L-h) ^a	
	Weapons Grade Isotopics	
	4.5 M Na ⁺	7.5 M Na ⁺
25	26.7	7.05
45	62.9	11.1
65	70.6	64.1

^a experimental limitations prevented obtaining removal rates for the low activity solutions near the Z-Area limits and for the high activity solutions at the heat source limits (1.6 µg/L for 4.5 M Na⁺ solutions and 1.8 µg/L for 7.5 M Na⁺ solutions).

Np-237 removal reached the Z-Area feed limit only in the tests with the lower ionic strength and lower neptunium concentration (see Table XIII). The neptunium removal rate increased with an increase in the temperature. Plutonium removal rates, but not strontium exhibited a similar behavior (see Tables XII and XI). For both plutonium and neptunium, the rates exhibited larger increases between 25 °C and 45 °C compared to 45 °C and 65 °C in the high activity solutions.

Table XIII. Incremental Removal Rates for Neptunium Upon Reaching Np-237 Limit for Feed of Decontaminated Salt Solution to Z-Area

Temp. (°C)	Incremental Rate (µg/L-h) ^a			
	4.5 M Na ⁺		7.5 M Na ⁺	
	Low Activity	High Activity	Low Activity	High Activity
25	33.6	exceeded limit	exceeded limit	exceeded limit
45	130	exceeded limit	exceeded limit	exceeded limit
65	155	exceeded limit	exceeded limit	exceeded limit

^a incremental rate determined for the time period during which the neptunium concentration passed through the Z-Area Np-237 limit (0.03 nCi/g – 51 µg/L for 4.5 M Na⁺ solutions and 56 µg/L for 7.5 M Na⁺ solutions) for decontaminated salt solution.

Batch Removal of Strontium, Plutonium, Uranium and Neptunium

An alternative facility design would achieve strontium and actinide removal in a feed preparation tank in the tank farm or in a separate batch tank preceding the tetraphenylborate precipitation tanks or the crystalline silicotitanate ion-exchange column in the salt processing facility. In these options, the sodium ion concentration in the feed solution could be as high as 7.5 M. Thus, design evaluation efforts require an understanding of the effect of ionic strength on removal rate. From inspection of the plots of sorbate concentration versus time (Figures 5-20), we determined the sampling interval during which the test had achieved equilibrium for the solutions at 4.5 and 7.5 M in Na⁺ and treated with 0.2 g/L MST. Table XIV presents these times.

Table XIV. Estimated Times from Sampling Intervals to Reach Equilibrium

Adsorbate	Time (h) ^a			
	4.5 M Low	7.5 M Low	4.5 M High	7.5 M High
Sr	8.6	49	8.5	8.3
Pu	8.6	50	25	25
Np	25	50	25	170
U	25	100	25	170

^a estimated times from inspection of Figures 5-20. Solutions include the 4.5 M Na⁺ (Z = 4.91 M) low and high activity solutions and the 7.5 M Na⁺ (Z = 8.20 M) low and high activity solutions.

For the low activity solution, increasing the ionic strength increased the time to reach equilibrium for all four sorbates. For the high activity solution, the time did not increase for strontium and

plutonium, but did increase for neptunium and uranium. This behavior suggests that removal rates depend on the ionic strength and the initial sorbate concentration for all of the sorbates with the possible exception of strontium. We recommend additional tests be conducted with more frequent sampling to provide a more accurate determination of when equilibrium is achieved.

Quality Assurance

This work used the following task plan.

W. R. Wilmarth, D. T. Hobbs and M. G. Bronikowski, "Phase III Test Plan for MST Adsorption Kinetics," WSRC-RP-98-00736, revision 0, August 10, 1998.

This document provides the final deliverable for the work requested in the authorizing task request,

P. L. Rutland, "MST Alpha Removal and Hg Removal for Salt Team Phase 3 Evaluation," HLE-TAR-98062, revision 0, July 15, 1998.

Notebooks WSRC-NB-98-00220, WSRC-NB-98-00268 and WSRC-NB-99-00061, (D. T. Hobbs) contain the experimental data obtained from this testing.

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References

1. P. L. Rutland, "MST Alpha Removal and Hg Removal for Salt Team Phase 3 Evaluation," HLE-TAR-98062, Rev. 0, July 15, 1998.
2. D. T. Hobbs and D. D. Walker, "Plutonium and Uranium Adsorption on Monosodium Titanate (U)," WSRC-RP-92-93, August 13, 1992.
3. D. T. Hobbs and S. D. Fleischman, "Fissile Solubility and Monosodium Titanate Loading Tests (U)," WSRC-RP-92-1273, February 12, 1993.
4. T. B. Edwards, "A Statistically Designed Experimental Plan Supporting LWP's Study of MST Adsorption Kinetics (U)," SRT-SCS-98-034, July 23, 1998.
5. D. T. Hobbs and S. D. Fleischman, "Fissile Solubility and Monosodium Titanate Loading Tests, WSRC-RP-92-1273, February 12, 1993.
6. "WSRC 241-82H Control Room Process Requirements," WSRC-IM-91-63, Rev. 20, October 1998.
7. "Chart of the Nuclides," Knolls Atomic Power Laboratory, Distributed by the General Electric Company, Schenectady, NY, October 1972.
8. N. E. Bibler, W. F. Kinard, W. T. Boyce and C. J. Coleman, "Determination of Long-Lived fission Products and Actinides in Savannah River Site HLW Sludge and Glass for Waste Acceptance," *Journal of Radioanalytical and Nuclear Chemistry*, 234 (1998), 159-163.
9. Memorandum from N. S. Dienes, "Plutonium Metal Feed Specification for Use in the Weapon Program Rocky Flats Plant, Volume I, Rev. A, March 22, 1985.

10. S. J. Snyder, "Characterization of HB-Line Low Level Waste (U)," WSRC-TR-94-0371, Rev. 0, August, 1994.
11. Electronic memo from J. R. Fowler to D. T. Hobbs, April 26, 1998. A copy of the memo is provided in Appendix 9.
12. Scot Beck, et al., "Bases, Assumptions and Results of the Flowsheet Calculations for the Short List Salt Disposition Alternatives," WSRC- RP-98-00168, Rev. 1, October 1998.
13. M. G. Bronikowski, D. T. Hobbs and W. R. Wilmarth, "Preliminary Report on Monosodium Titanate Adsorption Kinetics," WSRC-TR-98-00346, Rev. 0, October 5, 1998.
14. D. T. Hobbs, "Effects of Coprecipitation on the Concentrations of Uranium and Plutonium in Alkaline Salt Solutions," WSRC-TR-95-0462, November 30, 1995.
15. D. T. Hobbs, "Precipitation of Uranium and Plutonium from Alkaline Salt Solutions," **Nuclear Technology**, accepted for publication.

Appendix 1.
Average Concentration versus Time Data for Control Samples
6.0 M Na⁺, No Added MST
Low Activity Solutions - Bottles # 09 and 12
High Activity Solutions – Bottles # 02 and 06
(Units of Time = hours; Units of Concentration = µg/L)

Average of Blank Bottles #9 and #12 (6.0 M, Low Activity, no MST)

Time (h)	209/212 Sr	209/212 Pu	209/212 Np	209/212 U	Time (h)	409/412 Sr	409/412 Pu	409/412 Np	409/412 U	Time (h)	609/612 Sr	609/612 Pu	609/612 Np	609/612 U
2.25	6.62E+00	6.66E+00	1.14E+03	1.90E+03	2.22	6.62E+00	1.82E+00	7.07E+02	2.25E+03	2.2	6.26E+00	6.19E-01	4.27E+02	1.92E+03
4.2	6.57E+00	7.09E+00	9.94E+02	1.79E+03	4.22	6.56E+00	1.39E+00	7.30E+02	2.27E+03	4.2	6.26E+00	5.00E-01	4.32E+02	2.11E+03
8.17	6.52E+00	5.47E+00	1.12E+03	2.12E+03	8.22	6.34E+00	1.22E+00	5.90E+02	1.94E+03	8.23	6.19E+00	3.65E-01	3.78E+02	1.81E+03
24.13	6.17E+00	5.59E+00	1.09E+03	1.93E+03	24.33	5.49E+00	1.20E+00	5.56E+02	2.13E+03	24.1	4.72E+00	2.05E-01	3.39E+02	1.78E+03
48.17	5.75E+00	5.17E+00	1.27E+03	2.30E+03	48.22	4.96E+00	9.95E-01	5.08E+02	2.13E+03	48.1	4.32E+00	1.28E-01	3.03E+02	1.84E+03
168.02	4.89E+00	4.19E+00	9.78E+02	2.14E+03	95.7	3.93E+00	5.87E-01	4.29E+02	1.94E+03	96.07	3.73E+00	6.07E-02	2.99E+02	1.79E+03
239.8	4.71E+00	3.54E+00	9.48E+02	2.09E+03	168.02	1.84E+00	5.12E-01	3.68E+02	1.94E+03	167.88	3.37E+00	5.62E-02	2.69E+02	1.64E+03
Average	5.89E+00	5.39E+00	1.08E+03	2.04E+03	Average	5.11E+00	1.10E+00	5.56E+02	2.09E+03	Average	4.98E+00	2.76E-01	3.50E+02	1.84E+03
Std. Dev.	8.03E-01	1.26E+00	1.13E+02	1.75E+02	Std. Dev.	1.74E+00	4.57E-01	1.34E+02	1.45E+02	Std. Dev.	1.25E+00	2.23E-01	6.45E+01	1.48E+02
%RSD	13.64	23.35	10.45	8.56	%RSD	34.09	41.37	24.13	6.97	%RSD	25.11	80.56	18.44	8.03

Average of Bottles #2 and #6 (6.0 M, High Activity, no MST)

Time (h)	202/206 Sr	202/206 Pu	202/206 Np	202/206 U	Time (h)	402/406 Sr	402/406 Pu	402/406 Np	402/406 U	Time (h)	602/606 Sr	602/606 Pu	602/606 Np	602/606 U
1.95	8.60E+01	2.22E+02	3.01E+04	2.09E+04	2.12	8.48E+01	1.78E+02	2.71E+04	2.04E+04	2.12	7.95E+01	2.24E+02	3.37E+04	2.38E+04
4.13	8.58E+01	2.00E+02	2.65E+04	2.00E+04	4.13	8.61E+01		2.81E+04	2.05E+04	4.12	7.94E+01	2.09E+02	3.01E+04	2.08E+04
8.07	8.45E+01	2.20E+02	2.96E+04	2.01E+04	8.13	8.55E+01	1.81E+02	2.53E+04	1.93E+04	8.15	8.17E+01	1.85E+02	2.65E+04	2.01E+04
24.07	8.42E+01	1.84E+02	2.53E+04	1.78E+04	24.25	8.41E+01	2.10E+02	2.87E+04	1.94E+04	24.02	7.92E+01	1.86E+02	2.61E+04	1.91E+04
48.10	8.36E+01	2.03E+02	2.75E+04	1.91E+04	48.13	8.49E+01	2.06E+02	2.91E+04	2.03E+04	48.02	7.94E+01	1.86E+02	2.63E+04	1.95E+04
168.32	8.44E+01	2.19E+02	2.86E+04	1.97E+04	95.58	8.22E+01	1.98E+02	2.75E+04	1.96E+04	96	8.07E+01	2.05E+02	3.00E+04	2.19E+04
239.38	8.64E+01	2.07E+02	2.88E+04	2.04E+04	167.95	8.60E+01	2.24E+02	2.86E+04	2.02E+04	167.75	8.19E+01	1.94E+02	2.69E+04	1.97E+04
Average	8.50E+01	2.08E+02	2.81E+04	1.97E+04	Average	8.48E+01	1.99E+02	2.78E+04	2.00E+04	Average	8.02E+01	1.98E+02	2.85E+04	2.07E+04
Std. Dev.	1.06E+00	1.38E+01	1.69E+03	1.03E+03	Std. Dev.	1.33E+00	1.76E+01	1.29E+03	5.07E+02	Std. Dev.	1.17E+00	1.48E+01	2.85E+03	1.67E+03
%RSD	1.25	6.62	6.02	5.22	%RSD	1.57	8.83	4.66	2.54	%RSD	1.46	7.43	9.99	8.03

Appendix 2.
Strontium Concentrations in Control Samples

Appendix 3.
Plutonium Concentrations in Control Samples

Appendix 4.
Uranium Concentration in Control Samples

Appendix 5.
Neptunium Concentrations in Control Samples

Appendix 6. Equilibrium Distribution Constants at 25 °C

Bottle Number	[Na+] (M)	Z (M)	[MST] (g/L)	Activity	Special Note	[Sr]o (μg/L)	[Pu]o (μg/L)	[U]o (μg/L)	[Np]o (μg/L)	Kd Sr (mL/g)	Kd Pu (mL/g)	Kd U (mL/g)	Kd Np (mL/g)
7	6.0	6.55	1.1	high		8.48E+01	2.23E+02	1.97E+04	2.80E+04	1.33E+06	>9.4E4	1.58E+03	6.97E+02
32	6.0	6.55	1.1	high		8.48E+01	2.23E+02	1.97E+04	2.80E+04	1.95E+06	>9.4E4	1.22E+03	4.96E+02
3	6.0	6.55	1.1	high	a	8.48E+01	2.23E+02	1.97E+04	2.80E+04	8.42E+05	>9.4E4	1.32E+03	5.67E+02
13	6.0	6.55	1.1	high	a	8.48E+01	2.23E+02	1.97E+04	2.80E+04	7.41E+05	>9.4E4	1.08E+03	4.63E+02
5	6.0	6.55	1.1	high	b	8.48E+01	2.23E+02	1.97E+04	2.80E+04	7.01E+05	>9.4E4	1.55E+03	6.90E+02
19	6.0	6.55	1.1	high	c	8.48E+01	2.23E+02	1.97E+04	2.80E+04	8.29E+05	>9.4E4	1.05E+03	1.03E+03
10	6.0	6.55	1.1	low		6.62E+00	6.66E+00	2.04E+03	1.08E+03	1.57E+05	1.55E+04	2.23E+04	5.68E+04
24	6.0	6.55	1.1	low		6.62E+00	6.66E+00	2.04E+03	1.08E+03	1.48E+05	1.46E+04	2.03E+04	4.83E+04
16	6.0	6.55	1.1	low	a	6.62E+00	6.66E+00	2.04E+03	1.08E+03	1.08E+05	8.98E+03	1.84E+04	4.17E+04
26	6.0	6.55	1.1	low	a	6.62E+00	6.66E+00	2.04E+03	1.08E+03	1.38E+05	1.07E+04	1.95E+04	5.07E+04
21	6.0	6.55	1.1	low	b	6.62E+00	6.66E+00	2.04E+03	1.08E+03	1.27E+05	1.59E+04	2.00E+04	4.23E+04
14	6.0	6.55	1.1	low	c	6.62E+00	6.66E+00	2.04E+03	1.08E+03	2.59E+05	1.34E+05	2.13E+04	>4.85E+05
22	4.5	4.91	0.2	low		4.96E+00	1.12E+00	1.52E+03	3.40E+02	1.58E+05	3.35E+04	7.68E+03	8.55E+04
25	4.5	4.91	0.2	low		4.96E+00	1.12E+00	1.52E+03	3.40E+02	1.58E+05	3.93E+04	4.24E+03	6.69E+04
11	4.5	4.91	0.2	high		6.36E+01	1.68E+02	1.48E+04	2.10E+04	1.72E+06	>2.4E+05	7.93E+02	1.92E+03
31	4.5	4.91	0.2	high		6.36E+01	1.68E+02	1.48E+04	2.10E+04	1.92E+06	>2.0E+05	1.20E+03	2.46E+03
15	7.5	8.20	0.2	low		8.28E+00	9.83E+00	2.56E+03	1.70E+03	2.59E+04	1.17E+03	1.74E+03	1.12E+04
18	7.5	8.20	0.2	low		8.28E+00	9.83E+00	2.56E+03	1.70E+03	2.48E+04	1.10E+03	2.19E+03	1.28E+04
1	7.5	8.20	0.2	high		1.06E+02	2.80E+02	2.46E+04	3.50E+04	3.95E+05	>3.4E+05	3.17E+03	3.31E+03
28	7.5	8.20	0.2	high		1.06E+02	2.80E+02	2.46E+04	3.50E+04	3.91E+05	>3.4E+05	4.04E+03	3.96E+03
4	4.5	4.91	2.0	low		4.96E+00	1.12E+00	1.52E+03	3.40E+02	3.42E+05	5.56E+03	>3.8E+05	>8.4E+04
30	4.5	4.91	2.0	low		4.96E+00	1.12E+00	1.52E+03	3.40E+02	1.01E+05	2.65E+03	>6.5E+04	>8.4E+04
20	4.5	4.91	2.0	high		6.36E+01	1.68E+02	1.48E+04	2.10E+04	1.84E+06	>2.0E+04	3.37E+03	6.27E+02
29	4.5	4.91	2.0	high		6.36E+01	1.68E+02	1.48E+04	2.10E+04	>5.8E+05	>2.0E+04	3.45E+03	6.72E+02
8	7.5	8.20	2.0	low		8.28E+00	9.83E+00	2.56E+03	1.70E+03	3.58E+04	1.63E+03	7.46E+04	8.41E+04
23	7.5	8.20	2.0	low		8.28E+00	9.83E+00	2.56E+03	1.70E+03	3.41E+04	1.76E+03	9.08E+04	8.53E+04
17	7.5	8.20	2.0	high		1.06E+02	2.80E+02	2.46E+04	3.50E+04	2.03E+05	>3.4E+04	2.08E+03	4.81E+02
27	7.5	8.20	2.0	high		1.06E+02	2.80E+02	2.46E+04	3.50E+04	3.30E+05	>3.4E+04	1.98E+03	4.42E+02

Special Note: a = unmixed

b = 400 mg/L NaTPB

c = 400 mg/L sludge

Appendix 7.

Equilibrium Distribution Constants at 45 °C

Bottle Number	[Na+] (M)	Z (M)	[MST] (g/L)	Activity	Special Note	[Sr]o (μg/L)	[Pu]o (μg/L)	[U]o (μg/L)	[Np]o (μg/L)	Kd Sr (mL/g)	Kd Pu (mL/g)	Kd U (mL/g)	Kd Np (mL/g)
7	6.0	6.55	1.1	high		7.22E+01	2.14E+02	2.00E+04	2.78E+04	1.88E+06	>8.97E+04	1.63E+03	1.69E+03
32	6.0	6.55	1.1	high		7.22E+01	2.14E+02	2.00E+04	2.78E+04	2.22E+06	>8.97E+04	1.89E+03	1.33E+03
3	6.0	6.55	1.1	high	a	7.22E+01	2.14E+02	2.00E+04	2.78E+04	1.10E+06	>8.97E+04	1.61E+03	1.24E+03
13	6.0	6.55	1.1	high	a	7.22E+01	2.14E+02	2.00E+04	2.78E+04	1.05E+06	>8.97E+04	1.64E+03	1.37E+03
5	6.0	6.55	1.1	high	b	7.22E+01	2.14E+02	2.00E+04	2.78E+04	1.29E+06	>8.97E+04	1.60E+03	1.73E+03
19	6.0	6.55	1.1	high	c	7.22E+01	2.14E+02	2.00E+04	2.78E+04	6.25E+05	>8.97E+04	1.30E+03	1.33E+03
10	6.0	6.55	1.1	low		6.62E+00	7.50E-01	2.08E+03	7.82E+02	9.32E+04	2.10E+03	2.17E+04	>1.67E+05
24	6.0	6.55	1.1	low		6.62E+00	7.50E-01	2.08E+03	7.82E+02	1.02E+05	1.95E+03	1.84E+04	>1.67E+05
16	6.0	6.55	1.1	low	a	6.62E+00	7.50E-01	2.08E+03	7.82E+02	8.51E+04	8.27E+02	2.12E+04	>1.67E+05
26	6.0	6.55	1.1	low	a	6.62E+00	7.50E-01	2.08E+03	7.82E+02	7.93E+04	1.02E+03	1.75E+04	>1.67E+05
21	6.0	6.55	1.1	low	b	6.62E+00	7.50E-01	2.08E+03	7.82E+02	9.68E+04	5.14E+03	1.78E+04	>1.67E+05
14	6.0	6.55	1.1	low	c	6.62E+00	7.50E-01	2.08E+03	7.82E+02	8.45E+04	7.53E+03	1.68E+04	>1.67E+05
22	4.5	4.91	0.2	low		4.98E+00	1.74E+00	1.56E+03	5.88E+02	1.75E+05	5.63E+04	7.88E+03	1.07E+05
25	4.5	4.91	0.2	low		4.98E+00	1.74E+00	1.56E+03	5.88E+02	9.85E+04	3.12E+04	8.10E+03	>6.88E+05
11	4.5	4.91	0.2	high		5.42E+01	1.61E+02	1.50E+04	2.10E+04	9.97E+05	>3.70E+05	1.22E+03	5.39E+03
31	4.5	4.91	0.2	high		5.42E+01	1.61E+02	1.50E+04	2.10E+04	9.44E+05	>3.70E+05	1.32E+03	4.84E+03
15	7.5	8.20	0.2	low		8.28E+00	2.88E+00	2.60E+03	9.78E+02	2.24E+04	4.75E+03	3.61E+03	2.00E+04
18	7.5	8.20	0.2	low		8.28E+00	2.88E+00	2.60E+03	9.78E+02	2.75E+04	3.35E+03	3.18E+03	1.27E+04
1	7.5	8.20	0.2	high		9.02E+01	2.69E+02	2.50E+04	3.48E+04	2.83E+05	>6.20E+05	2.39E+03	5.60E+03
28	7.5	8.20	0.2	high		9.02E+01	2.69E+02	2.50E+04	3.48E+04	3.09E+05	>6.20E+05	2.96E+03	6.30E+03
4	4.5	4.91	2.0	low		4.98E+00	1.74E+00	1.56E+03	5.88E+02	2.80E+05	3.49E+03	>3.91E+05	>6.88E+04
30	4.5	4.91	2.0	low		4.98E+00	1.74E+00	1.56E+03	5.88E+02	1.68E+05	4.99E+03	>3.91E+05	>6.88E+04
20	4.5	4.91	2.0	high		5.42E+01	1.61E+02	1.50E+04	2.10E+04	8.59E+05	>3.70E+04	5.81E+03	1.90E+03
29	4.5	4.91	2.0	high		5.42E+01	1.61E+02	1.50E+04	2.10E+04	5.79E+05	>3.70E+04	6.24E+03	2.18E+03
8	7.5	8.20	2.0	low		8.28E+00	2.88E+00	2.60E+03	9.78E+02	2.13E+04	1.49E+03	1.37E+04	1.20E+04
23	7.5	8.20	2.0	low		8.28E+00	2.88E+00	2.60E+03	9.78E+02	2.15E+04	2.09E+03	1.27E+04	9.58E+03
17	7.5	8.20	2.0	high		9.02E+01	2.69E+02	2.50E+04	3.48E+04	6.33E+05	>6.20E+04	2.82E+03	1.33E+03
27	7.5	8.20	2.0	high		9.02E+01	2.69E+02	2.50E+04	3.48E+04	7.77E+05	>6.20E+04	2.72E+03	1.38E+03

Special Note: a = unmixed
b = 400 mg/L NaTPB
c = 400 mg/L sludge

Appendix 8

Equilibrium Distribution Constants at 65 °C

Bottle Numbe	[Na+] (M)	Z (M)	MST (g/L)	Activity	Special Note	[Sr]o (μg/L)	[Pu]o (μg/L)	[U]o (μg/L)	[Np]o (μg/L)	Kd Sr (mL/g)	Kd Pu (mL/g)	Kd U (mL/g)	Kd Np (mL/g)
7	6.0	6.55	1.1	high		8.02E+01	2.13E+02	2.08E+04	2.86E+04	1.76E+06	>8.93E+04	1.66E+03	1.13E+04
32	6.0	6.55	1.1	high		8.02E+01	2.13E+02	2.08E+04	2.86E+04	1.01E+06	>8.93E+04	1.68E+03	1.18E+04
3	6.0	6.55	1.1	high	a	8.02E+01	2.13E+02	2.08E+04	2.86E+04	9.65E+05	>8.93E+04	1.55E+03	1.12E+04
13	6.0	6.55	1.1	high	a	8.02E+01	2.13E+02	2.08E+04	2.86E+04	1.07E+06	>8.93E+04	1.60E+03	1.29E+04
5	6.0	6.55	1.1	high	b	8.02E+01	2.13E+02	2.08E+04	2.86E+04	7.63E+05	>8.93E+04	1.72E+03	1.15E+04
19	6.0	6.55	1.1	high	c	8.02E+01	2.13E+02	2.08E+04	2.86E+04	5.10E+05	>8.93E+04	1.22E+03	4.85E+03
10	6.0	6.55	1.1	low		6.62E+00	7.50E-01	1.84E+03	4.72E+02	5.16E+04	4.76E+03	1.55E+04	>4.69E+04
24	6.0	6.55	1.1	low		6.62E+00	7.50E-01	1.84E+03	4.72E+02	5.41E+04	2.41E+03	1.20E+04	>1.20E+05
16	6.0	6.55	1.1	low	a	6.62E+00	7.50E-01	1.84E+03	4.72E+02	5.80E+04	3.77E+03	1.77E+04	>1.20E+05
26	6.0	6.55	1.1	low	a	6.62E+00	7.50E-01	1.84E+03	4.72E+02	6.11E+04	2.69E+03	1.36E+04	>1.20E+05
21	6.0	6.55	1.1	low	b	6.62E+00	7.50E-01	1.84E+03	4.72E+02	3.65E+04	4.46E+03	1.28E+04	>1.20E+05
14	6.0	6.55	1.1	low	c	6.62E+00	7.50E-01	1.84E+03	4.72E+02	3.24E+04	6.92E+03	2.14E+04	>1.20E+05
22	4.5	4.91	0.2	low		4.98E+00	5.60E-01	1.38E+03	3.54E+02	6.47E+04	1.34E+04	7.46E+03	>4.92E+05
25	4.5	4.91	0.2	low		4.98E+00	5.60E-01	1.38E+03	3.54E+02	9.17E+04	6.94E+03	8.22E+03	>4.92E+05
11	4.5	4.91	0.2	high		6.04E+01	1.60E+02	1.56E+04	2.16E+04	5.43E+05	>3.68E+05	1.73E+03	1.01E+04
31	4.5	4.91	0.2	high		6.04E+01	1.60E+02	1.56E+04	2.16E+04	6.49E+05	>3.68E+05	1.91E+03	1.02E+04
15	7.5	8.20	0.2	low		8.28E+00	1.12E+00	2.30E+03	5.90E+02	2.49E+04	1.01E+04	4.06E+03	1.11E+04
18	7.5	8.20	0.2	low		8.28E+00	1.44E+00	2.30E+03	5.90E+02	2.69E+04	8.42E+03	3.43E+03	1.37E+04
1	7.5	8.20	0.2	high		1.00E+02	2.67E+02	2.60E+04	3.58E+04	2.14E+05	>6.15E+05	3.32E+03	1.09E+04
28	7.5	8.20	0.2	high		1.00E+02	2.67E+02	2.60E+04	3.58E+04	2.30E+05	>6.15E+05	2.56E+03	9.02E+03
4	4.5	4.91	2.0	low		4.98E+00	5.60E-01	1.38E+03	3.54E+02	2.75E+05	1.13E+03	>3.46E+05	>4.92E+04
30	4.5	4.91	2.0	low		4.98E+00	5.60E-01	1.38E+03	3.54E+02	2.50E+05	9.60E+02	>3.46E+05	>4.92E+04
20	4.5	4.91	2.0	high		6.04E+01	1.60E+02	1.56E+04	2.16E+04	5.39E+05	>3.68E+04	4.02E+03	3.68E+04
29	4.5	4.91	2.0	high		6.04E+01	1.60E+02	1.56E+04	2.16E+04	5.56E+05	>3.68E+04	5.05E+03	4.57E+04
8	7.5	8.20	2.0	low		8.28E+00	5.60E-01	2.30E+03	5.90E+02	2.99E+04	8.30E+02	1.13E+04	>8.24E+04
23	7.5	8.20	2.0	low		8.28E+00	5.60E-01	2.30E+03	5.90E+02	2.29E+04	1.44E+03	9.00E+03	>8.24E+04
17	7.5	8.20	2.0	high		1.00E+02	2.67E+02	2.60E+04	3.58E+04	6.01E+05	>6.15E+04	1.75E+03	8.82E+03
27	7.5	8.20	2.0	high		1.00E+02	2.67E+02	2.60E+04	3.58E+04	5.09E+05	>6.15E+04	1.74E+03	8.31E+03

Special Note: a = unmixed
b = 400 mg/L NaTPB
c = 400 mg/L sludge

Appendix 9

Calculation of Np-237 Concentration in SRS High-Level Waste

Author: John Fowler at SRCCH02
Date: 4/26/99 5:55 PM
Priority: Normal
To: David Hobbs at SRCCA03
Subject: Re: Np Reference

I think all I had was an e-mail, which I didn't archive. Paul Rutland may have a copy. In any case, here's a calculation based on data in Table D1(a) and D1(c) in Appendix D of the "Bases, Assumptions, and Results of the Flowsheet Calculations for the Short List Salt Disposition Alternatives," WSRC-RP-98-00168, Revision 1, [Scott Beck et al.].

D1(a) shows Tanks 33 and 34 have the most Np-237 inventory from the WCS data base. All other tanks are at least a factor of 10 lower in total Ci of Np.

Tank 33 contains 191,700 gallons of free supernate with a sp. g. of 1.18. This solution has 0.613 Ci of Np-237 dissolved in it, and would generate 90,600 gallons of 6.45 M Na⁺ to feed one of the processes. The Specific Activity for Np-237 = 7.05E-4 Ci/g.

$$0.613 \text{ Ci} / (3.7854 \text{ L/gal} \times 90,600 \text{ gal}) = 1.8\text{E-}6 \text{ Ci/L} @ 6.45 \text{ M Na}^+$$

$$(1.8\text{E-}6 \text{ Ci/L}) / (7.05\text{E-}4 \text{ Ci/g}) = 2.5\text{E-}3 \text{ g/L or } 2.5 \text{ mg/L}$$

Tank 33 solution still has to be evaporated, so it likely isn't representative of what would be really be present in 6.45 M feed.

Tank 34 contains 920,900 gallons of free supernate with a sp g of 1.38 that would yield 1.488E6 gallons of 6.45 M feed solution. This supernate has 1.79 Ci of Np-237. The sp g shows it has been at partially processed through the evaporator, and would be diluted slightly to be at 6.45 M Na⁺. Here's the calc for this solution:

$$1.79 \text{ Ci} / (3.7854 \text{ L/gal} \times 1,488,000 \text{ gal}) = 3.2\text{E-}7 \text{ Ci/L}$$

$$(3.2\text{E-}7 \text{ Ci/L}) / (7.05\text{E-}4 \text{ Ci/g}) = 4.5\text{E-}4 \text{ g/L or } 0.45 \text{ mg/L} @ 6.45 \text{ M Na}^+$$

Bounding concentration in existing waste is thus 2.5 mg/L @6.45 M Na⁺ in Tank 33, although < 0.5 mg/L is more representative of stuff that's been evaporated. The Np-237 inventory in free supernate in all other tanks are at least a factor of 10 below Tank 34.

Appendix 10.
Concentration versus Time Data for Tests at
4.5 M Na⁺, 0.2 g/L MST, Low Activity Solution
(Bottles # 22 and 25)
(Units of Time = hours; Units of Concentration = µg/L)

222 Time	222 Sr	222 Pu	222 Np	222 U	422 Time	422 Sr	422 Pu	422 Np	422 U	622 Time	622 Sr	622 Pu	622 Np	622 U
0	4.96E+00	1.12E+00	3.40E+02	1.52E+03	0	4.98E+00	1.74E+00	5.88E+02	1.56E+03	0	4.98E+00	5.60E-01	3.54E+02	1.38E+03
2.40	8.67E-01	1.99E-01	1.33E+02	1.34E+03	2.53	1.38E-01	5.38E-02	4.40E+01	9.77E+02	2.25	6.28E-01	2.43E-02	2.22E+00	8.46E+02
4.33	3.87E-01	2.57E-01	4.08E+01	1.02E+03	4.53	1.13E-01	9.89E-02	2.14E+00	8.43E+02	4.23	1.82E-01	3.29E-02	2.18E+00	6.95E+02
8.33	2.67E-01	1.92E-02	4.37E+01	9.72E+02	8.53	9.06E-02	9.03E-02	3.24E+01	8.61E+02	8.30	1.83E-01	7.51E-02	2.50E+00	7.01E+02
24.28	1.89E-01	4.85E-02	2.00E+00	7.24E+02	24.65	8.94E-02	7.21E-02	4.23E+01	8.11E+02	24.12	2.48E-01	7.17E-02	2.78E+00	5.36E+02
48.28	1.59E-01	1.50E-01			48.50	1.07E-01	1.42E-01	3.65E+01	1.10E+03	48.17	2.83E-01	1.25E-01	1.22E+01	5.58E+02
168.13	1.75E-01	1.62E-01	2.48E+01	6.70E+02	95.98	1.38E-01	1.40E-01	2.26E+01	5.94E+02	96.01	2.64E-01	1.50E-01	2.06E+01	5.59E+02
239.95	1.52E-01	1.46E-01	1.88E+01	5.98E+02	168.27	2.88E-01	6.34E-02	2.62E+01	6.07E+02	167.92	3.57E-01	1.52E-01	3.56E+00	5.56E+02

225 Time	225 Sr	225 Pu	225 Np	225 U	425 Time	425 Sr	425 Pu	425 Np	425 U	625 Time	625 Sr	625 Pu	625 Np	625 U
0	4.96E+00	1.12E+00	3.40E+02	1.52E+03	0	4.98E+00	1.74E+00	5.88E+02	1.56E+03	0	4.98E+00	5.60E-01	3.54E+02	1.38E+03
2.43	9.08E-01	1.58E-02	1.03E+02	1.28E+03	2.60	1.44E-01	8.96E-02	3.38E+01	1.01E+03	2.28	5.58E-01	2.72E-02	2.22E+00	8.09E+02
4.40	3.48E-01	5.44E-02	6.41E+01	1.14E+03	4.60	1.10E-01	3.08E-02	2.14E+00	8.73E+02	4.25	1.90E-01	4.43E-02	2.18E+00	6.89E+02
8.38	2.60E-01	1.92E-02	6.97E+01	9.94E+02	8.60	9.40E-02	4.65E-02	3.63E+01	8.68E+02	8.35	1.44E-01	1.37E-01	2.50E+00	6.61E+02
24.32	1.98E-01	1.10E-01	2.00E+00	7.52E+02	24.73	9.63E-02	1.96E-01	2.82E+01	9.44E+02	24.15	2.34E-01	1.51E-01	2.78E+00	5.08E+02
48.33	1.61E-01	1.95E-01			48.57	9.45E-02	5.47E-02	3.08E+00	5.82E+02	48.28	2.44E-01	1.26E-01	1.81E+01	5.75E+02
168.17	1.84E-01	1.77E-01	2.58E+01	6.90E+02	96.07	1.26E-01	2.37E-01	3.64E+00	5.80E+02	96.15	3.05E-01		3.12E+00	5.88E+02
239.98	1.53E-01	1.26E-01	2.37E+01	6.26E+02	168.32	2.41E-01	2.40E-01	4.24E+00	5.97E+02	167.92	2.57E-01	2.35E-01	3.56E+00	5.24E+02

Averages of Duplicate Tests - Bottle #22 and #25

Time	25 Sr	25 Pu	25 Np	25 U	45 Time	45 Sr	45 Pu	45 Np	45 U	65 Time	65 Sr	65 Pu	65 Np	65 U
0	4.96E+00	1.12E+00	3.40E+02	1.52E+03	0	4.98E+00	1.74E+00	5.88E+02	1.56E+03	0	4.98E+00	5.60E-01	3.54E+02	1.38E+03
2.415	8.87E-01	1.07E-01	1.18E+02	1.31E+03	2.565	1.41E-01	7.17E-02	3.89E+01	9.94E+02	2.265	5.93E-01	2.58E-02	2.22E+00	8.28E+02
4.365	3.68E-01	1.56E-01	5.25E+01	1.08E+03	4.565	1.12E-01	6.48E-02	2.14E+00	8.58E+02	4.24	1.86E-01	3.86E-02	2.18E+00	6.92E+02
8.355	2.63E-01	1.92E-02	5.67E+01	9.83E+02	8.565	9.23E-02	6.84E-02	3.44E+01	8.65E+02	8.325	1.64E-01	1.06E-01	2.50E+00	6.81E+02
24.3	1.93E-01	7.93E-02	2.00E+00	7.38E+02	24.69	9.28E-02	1.34E-01	3.53E+01	8.78E+02	24.135	2.41E-01	1.11E-01	2.78E+00	5.22E+02
48.305	1.60E-01	1.73E-01			48.535	1.01E-01	9.81E-02	1.98E+01	8.43E+02	48.225	2.64E-01	1.26E-01	1.51E+01	5.67E+02
168.15	1.79E-01	1.69E-01	2.53E+01	6.80E+02	96.025	1.32E-01	1.89E-01	1.31E+01	5.87E+02	96.08	2.84E-01	1.50E-01	1.19E+01	5.73E+02
239.965	1.52E-01	1.36E-01	2.12E+01	6.12E+02	168.295	2.64E-01	1.52E-01	1.52E+01	6.02E+02	167.92	3.07E-01	1.93E-01	3.56E+00	5.40E+02

Appendix 11.
Concentration versus Time Data for Tests at
4.5 M Na⁺, 2.0 g/L MST, Low Activity Solution
(Bottles # 04 and 30)

(Units of Time = hours; Units of Concentration = µg/L)

204 Time	204 Sr	204 Pu	204 Np	204 U	404 Time	404 Sr	404 Pu	404 Np	404 U	604 Time	604 Sr	604 Pu	604 Np	604 U
0	4.96E+00	1.14E+00	3.40E+02	1.52E+03	0	4.98E+00	1.74E+00	5.88E+02	1.56E+03	0	4.98E+00	5.60E-01	3.54E+02	1.38E+03
2.18	1.76E-01	7.01E-02	2.00E+00	3.46E+02	2.07	1.35E-02	2.93E-02	1.35E+01	1.27E+02	2.03	1.21E-01		2.22E+00	8.35E+01
4.15	4.97E-02	4.92E-02	1.88E+01	1.14E+02	4.07	5.46E-03	2.22E-02	2.14E+00	2.00E+00	4.03	1.63E-02	7.73E-02	2.18E+00	3.60E+01
8.13	3.75E-02	1.92E-02	2.00E+00	9.88E+01	8.07	1.16E-02	3.04E-02	2.66E+00	4.60E+01	8.08	2.48E-02	7.25E-02	2.50E+00	2.75E+01
24.12	4.24E-02	8.32E-01	2.00E+00	2.00E+00	24.20	1.27E-02	4.21E-01	2.82E+00	2.00E+00	23.95	1.16E-02	1.44E-01	2.78E+00	2.00E+00
48.13	3.96E-02	9.46E-03	2.00E+00	2.00E+00	48.08	8.87E-03	2.85E-01	3.08E+00	2.00E+00	47.97	1.65E-02	1.69E-01	3.12E+00	1.70E+01
167.98	7.23E-03	4.62E-02	2.00E+00	2.00E+00	95.53	0.00E+00	4.54E-01	3.64E+00	1.68E+01	95.93	9.04E-03	1.75E-01	3.12E+00	2.00E+00
239.75	1.74E-03	9.40E-02	2.00E+00	2.00E+00	167.90	3.60E-02	2.18E-01	4.24E+00	1.13E+01	167.65	4.97E-04	1.72E-01	3.56E+00	2.00E+00
230 Time	230 Sr	230 Pu	230 Np	230 U	430 Time	430 Sr	430 Pu	430 Np	430 U	630 Time	630 Sr	630 Pu	630 Np	630 U
0	4.96E+00	1.14E+00	3.40E+02	1.52E+03	0	4.98E+00	1.74E+00	5.88E+02	1.56E+03	0	4.98E+00	5.60E-01	3.54E+02	1.38E+03
2.45	2.30E-01	5.14E-02	5.76E+01	3.86E+02	2.73	1.54E-02	9.06E-02	2.22E+00	2.86E+02	2.30	1.15E-01	7.83E-02	2.22E+00	7.97E+01
4.42	3.97E-02	7.86E-02	1.29E+01	1.23E+02	4.73	1.68E-02	7.25E-03	2.14E+00	2.00E+00	4.27	7.10E-03	1.94E-02	2.18E+00	2.00E+00
8.57	5.38E-02	3.75E-02	2.00E+00	1.03E+02	8.70	8.15E-03	4.17E-02	2.66E+00	5.00E+01	7.37	1.95E-02	6.17E-02	2.50E+00	2.00E+00
24.33	3.95E-02	1.25E-01	2.00E+00	2.00E+00	24.83	1.66E-02	9.78E-02	2.82E+00	2.00E+00	24.17	1.07E-02	2.14E-01	2.78E+00	2.00E+00
48.35	3.19E-02	1.10E-01	0.00E+00	2.00E+00	48.67	7.82E-03	1.44E-01	3.08E+00	2.00E+00	48.28	9.92E-03	1.08E-01	1.11E+01	1.18E+02
168.10	1.50E-03	1.17E-01	2.00E+00	2.00E+00	96.17	1.58E-02	3.28E-01	3.64E+00	1.47E+01	96.15	3.48E-03	1.14E-01	3.12E+00	5.22E+01
239.98	2.45E-02	1.80E-01	2.00E+00	1.16E+01	168.43	1.48E-02	1.58E-01	4.24E+00	2.00E+00	167.93	0.00E+00	1.92E-01	3.56E+00	2.00E+00
Averages of Duplicate Tests - Bottle #4 and #30														
Time	25 Sr	25 Pu	25 Np	25 U	45 Time	45 Sr	45 Pu	45 Np	45 U	65 Time	65 Sr	65 Pu	65 Np	65 U
0	4.96E+00	1.14E+00	3.40E+02	1.52E+03	0	4.98E+00	1.74E+00	5.88E+02	1.56E+03	0	4.98	0.560268	3.54E+02	1.38E+03
2.315	2.03E-01	6.08E-02	2.98E+01	3.66E+02	2.4	1.44E-02	6.00E-02	7.86E+00	2.06E+02	2.165	0.11802	0.078333	2.22E+00	8.16E+01
4.285	4.47E-02	6.39E-02	1.59E+01	1.19E+02	4.4	1.11E-02	1.47E-02	2.14E+00	2.00E+00	4.15	0.01168	0.048306	2.18E+00	1.90E+01
8.35	4.57E-02	2.84E-02	2.00E+00	1.01E+02	8.385	9.89E-03	3.61E-02	2.66E+00	4.80E+01	7.725	0.022126	0.067114	2.50E+00	1.47E+01
24.225	4.10E-02	4.79E-01	2.00E+00	2.00E+00	24.515	1.47E-02	2.59E-01	2.82E+00	2.00E+00	24.06	0.011183	0.179033	2.78E+00	2.00E+00
48.24	3.57E-02	5.98E-02	1.00E+00	2.00E+00	48.375	8.34E-03	2.14E-01	3.08E+00	2.00E+00	48.125	0.01321	0.138331	7.10E+00	6.74E+01
168.04	4.37E-03	8.14E-02	2.00E+00	2.00E+00	95.85	7.88E-03	3.91E-01	3.64E+00	1.58E+01	96.04	0.006262	0.144308	3.12E+00	2.71E+01
239.865	1.31E-02	1.37E-01	2.00E+00	6.81E+00	168.165	2.54E-02	1.88E-01	4.24E+00	6.64E+00	167.79	0.000248	0.18188	3.56E+00	2.00E+00

Appendix 12.
Concentration versus Time Data for Tests at
6.0 M Na⁺, 1.1 g/L MST, Low Activity Solution
(Bottles # 10 and 24)
 (Units of Time = hours; Units of Concentration = µg/L)

210 Time	210 Sr	210 Pu	210 Np	210 U	410 Time	410 Sr	410 Pu	410 Np	410 U	610 Time	610 Sr	610 Pu	610 Np	610 U
0	6.62E+00	6.66E+00	1.08E+03	2.04E+03	0	6.62E+00	7.50E-01	7.82E+02	2.08E+03	0	6.62E+00	7.50E-01	4.72E+02	1.84E+03
2.28	3.86E-01	1.61E+00	2.37E+02	1.09E+03	2.25	1.26E-01	3.19E-01	3.07E+01	5.34E+02	2.15	2.98E-01	8.49E-02	2.22E+00	2.98E+02
4.23	1.23E-01	1.05E+00	1.01E+02	5.63E+02	4.25	1.20E-01	1.77E-01	2.14E+00	2.00E+00	4.12	1.42E-01	5.42E-03	2.18E+00	2.16E+02
8.20	8.95E-02	9.21E-01	7.00E+01	6.29E+02	8.23	7.76E-02	1.21E-01	2.66E+00	2.12E+02	8.18	9.69E-02	6.17E-02	2.50E+00	1.43E+02
24.17	5.52E-02	3.01E-01	2.00E+00	3.11E+02	24.37	5.36E-02	1.52E-01	2.82E+00	1.19E+02	24.03	1.11E-01	8.65E-02	2.78E+00	1.00E+02
48.18	5.04E-02	9.46E-03	2.00E+00	2.42E+02	48.23	7.36E-02	1.73E-01	3.08E+00	9.47E+01	48.03	8.77E-02	1.10E-01	8.95E+00	1.33E+02
168.05	4.06E-02	2.91E-01	2.00E+00	8.23E+01	95.72	6.40E-02	3.65E-01	3.64E+00	8.43E+01	95.98	1.39E-01	1.24E-01	3.12E+00	8.00E+01
239.85	3.81E-02	3.69E-01	1.70E+01	7.97E+01	168.03		2.27E-01	4.24E+00	8.36E+01	167.83	1.15E-01	1.20E-01	3.56E+00	1.02E+02
224 Time	224 Sr	224 Pu	224 Np	224 U	424 Time	424 Sr	424 Pu	424 Np	424 U	624 Time	624 Sr	624 Pu	624 Np	624 U
0	6.62E+00	6.66E+00	1.08E+03	2.04E+03	0	6.62E+00	7.50E-01	7.82E+02	2.08E+03	0	6.62E+00	7.50E-01	4.72E+02	1.84E+03
2.42	3.19E-01	1.19E+00	3.10E+02	1.11E+03	2.57	1.25E-01	1.97E-01	4.89E+01	5.67E+02	2.27	3.26E-01	9.70E-02	2.22E+00	3.48E+02
4.37	1.32E-01	9.11E-01	1.30E+02	7.64E+02	4.58	1.24E-01	1.48E-01	2.14E+00	2.00E+00	4.23	1.36E-01	5.58E-02	2.18E+00	1.81E+02
8.40	9.35E-02	8.94E-01	8.64E+01	5.31E+02	8.57	8.61E-02	1.81E-01	2.66E+00	2.57E+02	8.33	7.49E-02	1.03E-01	2.50E+00	1.12E+02
24.30	5.87E-02	4.87E-01	2.00E+00	2.84E+02	24.70	4.71E-02	1.96E-01	2.82E+00	1.38E+02	24.13	1.01E-01	1.24E-01	2.78E+00	2.00E+00
48.32	4.84E-02	5.80E-01	2.00E+00	2.00E+00	48.55	4.86E-02	1.19E-01	3.08E+00	8.20E+01	48.23	9.19E-02	8.99E-02	3.12E+00	1.29E+02
168.15	4.62E-02	5.69E-01	2.57E+01	9.92E+01	96.05	5.84E-02	5.06E-01	3.64E+00	8.45E+01	96.13	1.05E-01	5.19E-02	3.12E+00	8.57E+01
239.97	4.04E-02	3.89E-01	1.99E+01	8.72E+01	168.30	1.22E-01	2.38E-01	4.24E+00	9.79E+01	167.92	1.09E-01	2.06E-01	3.56E+00	1.30E+02
Averages of Duplicate Tests - Bottle #10 and #24														
Time	25 Sr	25 Pu	25 Np	25 U	45 Time	45 Sr	45 Pu	45 Np	45 U	65 Time	65 Sr	65 Pu	65 Np	65 U
0	6.62E+00	6.66E+00	1.08E+03	2.04E+03	0	6.62E+00	7.50E-01	7.82E+02	2.08E+03	0	6.62E+00	7.50E-01	4.72E+02	1.84E+03
2.35	3.52E-01	1.40E+00	2.73E+02	1.10E+03	2.41	1.26E-01	2.58E-01	3.98E+01	5.51E+02	2.21	3.12E-01	9.10E-02	2.22E+00	3.23E+02
4.3	1.27E-01	9.81E-01	1.15E+02	6.64E+02	4.415	1.22E-01	1.63E-01	2.14E+00	2.00E+00	4.175	1.39E-01	3.06E-02	2.18E+00	1.98E+02
8.3	9.15E-02	9.07E-01	7.82E+01	5.80E+02	8.4	8.19E-02	1.51E-01	2.66E+00	2.34E+02	8.255	8.59E-02	8.21E-02	2.50E+00	1.28E+02
24.235	5.70E-02	3.94E-01	2.00E+00	2.98E+02	24.535	5.04E-02	1.74E-01	2.82E+00	1.29E+02	24.08	1.06E-01	1.05E-01	2.78E+00	5.10E+01
48.25	4.94E-02	2.95E-01	2.00E+00	1.22E+02	48.39	6.11E-02	1.46E-01	3.08E+00	8.83E+01	48.13	8.98E-02	1.00E-01	6.04E+00	1.31E+02
168.1	4.34E-02	4.30E-01	1.39E+01	9.08E+01	95.885	6.12E-02	4.36E-01	3.64E+00	8.44E+01	96.055	1.22E-01	8.80E-02	3.12E+00	8.28E+01
239.91	3.92E-02	3.79E-01	1.85E+01	8.35E+01	168.165	1.22E-01	2.32E-01	4.24E+00	9.08E+01	167.875	1.12E-01	1.63E-01	3.56E+00	1.16E+02

Appendix 13.
Concentration versus Time Data for Tests at
6.0 M Na⁺, 1.1 g/L MST, Low Activity Solution, No Mixing
(Bottles # 16 and 26)

(Units of Time = hours; Units of Concentration = µg/L)

216 Time	216 Sr	216 Pu	216 Np	216 U	416 Time	416 Sr	416 Pu	416 Np	416 U	616 Time	616 Sr	616 Pu	616 Np	616 U
0	6.62E+00	6.66E+00	1.08E+03	2.04E+03	0	6.62E+00	7.50E-01	7.82E+02	2.08E+03	0	6.62E+00	7.50E-01	4.72E+02	1.84E+03
2.17	1.90E-01	1.02E+00	1.58E+02	7.96E+02	2.87	8.73E-02	1.45E-01	1.59E+01	4.84E+02	2.08	1.11E-01	4.85E-02	2.22E+00	2.90E+02
4.40	1.13E-01	3.80E-01	6.33E+01	5.66E+02	4.87	8.33E-02	1.72E-01	2.14E+00	2.00E+00	4.05	1.16E-01	1.40E-02	2.18E+00	2.13E+02
8.47	9.36E-02	7.75E-01	6.02E+01	4.65E+02	8.87	9.61E-02	5.28E-02	2.66E+00	2.87E+02	8.03	9.51E-02	5.37E-02	2.50E+00	1.43E+02
24.35	8.44E-02	6.71E-01	8.38E+01	3.90E+02	25.02	9.29E-02	5.00E-02	4.34E+01	2.33E+02	24.13	9.59E-02	5.59E-02	2.78E+00	1.03E+02
48.35	8.04E-02	4.56E-01	2.00E+00	2.00E+00	48.82	7.06E-02	1.26E-01	3.08E+00	1.08E+02	48.07	1.08E-01	1.47E-01	9.92E+00	1.25E+02
168.17	5.89E-02	6.15E-01	3.04E+01	1.07E+02	96.50	7.00E-02	3.91E-01	1.83E+01	8.54E+01	96.00	9.44E-02	1.20E-02	3.12E+00	9.80E+01
240.00	5.54E-02	6.12E-01	2.30E+01	9.60E+01	168.62	1.42E-01	3.93E-01	4.24E+00	3.11E+02	167.87	1.02E-01	1.46E-01	3.56E+00	8.98E+01
226 Time	226 Sr	226 Pu	226 Np	226 U	426 Time	426 Sr	426 Pu	426 Np	426 U	626 Time	626 Sr	626 Pu	626 Np	626 U
0	6.62E+00	6.66E+00	1.08E+03	2.04E+03	0	6.62E+00	7.50E-01	7.82E+02	2.08E+03	0	6.62E+00	7.50E-01	4.72E+02	1.84E+03
2.45	1.73E-01	7.92E-01	2.26E+02	9.99E+02	2.90	1.38E-01	1.58E-01	2.98E+01	4.56E+02	2.10	1.24E-01	7.19E-02	2.22E+00	2.73E+02
4.42	1.01E-01	8.85E-01	8.51E+01	4.98E+02	4.90	1.30E-01	1.90E-01	2.14E+00	2.00E+00	4.07	1.20E-01	1.08E-01	2.18E+00	2.57E+02
8.32	8.86E-02	4.96E-01	6.77E+01	4.97E+02	8.90	1.18E-01	2.33E-01	2.66E+00	2.71E+02	8.03	7.23E-02	1.20E-01	2.50E+00	1.27E+02
24.37	8.37E-02	7.16E-01	7.85E+01	3.81E+02	25.03	1.07E-01	2.68E-01	3.67E+01	2.00E+02	24.15	1.04E-01	1.14E-01	2.78E+00	1.31E+02
48.37	6.73E-02	6.95E-01	2.00E+00	2.00E+00	48.83	8.02E-02	1.18E-01	3.08E+00	1.05E+02	49.07	9.46E-02	1.17E-01	8.77E+00	1.15E+02
168.18	6.33E-02	6.10E-01	2.00E+00	1.47E+02	96.43	7.50E-02	5.37E-01	3.64E+00	1.25E+02	96.02	1.02E-01		3.12E+00	8.55E+01
240.00	4.34E-02	5.23E-01	1.90E+01	9.09E+01	168.63	2.39E-01	3.53E-01	4.24E+00	1.03E+02	167.88	9.71E-02	1.90E-01	3.56E+00	1.16E+02
Averages of Duplicate Tests - Bottle #16 and #26														
Time	25 Sr	25 Pu	25 Np	25 U	45 Time	45 Sr	45 Pu	45 Np	45 U	65 Time	65 Sr	65 Pu	65 Np	65 U
0	6.62E+00	6.66E+00	1.08E+03	2.04E+03	0	6.62E+00	7.50E-01	7.82E+02	2.08E+03	0	6.62E+00	7.50E-01	4.72E+02	1.84E+03
2.31	1.81E-01	9.06E-01	1.92E+02	8.98E+02	2.885	1.13E-01	1.52E-01	2.28E+01	4.70E+02	2.09	1.17E-01	6.02E-02	2.22E+00	2.81E+02
4.41	1.07E-01	6.33E-01	7.42E+01	5.32E+02	4.885	1.07E-01	1.81E-01	2.14E+00	2.00E+00	4.06	1.18E-01	6.11E-02	2.18E+00	2.35E+02
8.395	9.11E-02	6.35E-01	6.39E+01	4.81E+02	8.885	1.07E-01	1.43E-01	2.66E+00	2.79E+02	8.03	8.37E-02	8.71E-02	2.50E+00	1.35E+02
24.36	8.41E-02	6.93E-01	8.11E+01	3.85E+02	25.025	9.99E-02	1.59E-01	4.00E+01	2.17E+02	24.14	9.99E-02	8.52E-02	2.78E+00	1.17E+02
48.36	7.38E-02	5.76E-01	2.00E+00	2.00E+00	48.825	7.54E-02	1.22E-01	3.08E+00	1.07E+02	48.57	1.01E-01	1.32E-01	9.34E+00	1.20E+02
168.175	6.11E-02	6.12E-01	1.62E+01	1.27E+02	96.465	7.25E-02	4.64E-01	1.10E+01	1.05E+02	96.01	9.80E-02	1.20E-02	3.12E+00	9.18E+01
240	4.94E-02	5.68E-01	2.10E+01	9.35E+01	168.625	1.90E-01	3.73E-01	4.24E+00	2.07E+02	167.875	9.96E-02	1.68E-01	3.56E+00	1.03E+02

Appendix 14.
Concentration versus Time Data for Tests at
46.0 M Na⁺, 1.1 g/L MST, Low Activity Solution, NaTPB or Sludge Added
(Bottles # 21 and 14)
(Units of Time = hours; Units of Concentration = µg/L)

400 mg/L NaTPB

221 Time	221 Sr	221 Pu	221 Np	221 U	421 Time	421 Sr	421 Pu	421 Np	421 U	621 Time	621 Sr	621 Pu	621 Np	621 U
0	6.62E+00	6.66E+00	1.08E+03	2.04E+03	0	6.62E+00	7.50E-01	7.82E+02	2.08E+03	0	6.62E+00	7.50E-01	4.72E+02	1.84E+03
2.38	3.32E-01	1.42E+00	2.30E+02	9.04E+02	2.50	1.30E-01	1.51E-01	3.96E+01	5.93E+02	2.27	2.95E-01	3.08E-02	2.22E+00	3.73E+02
4.32	1.33E-01	6.90E-01	1.20E+02	6.85E+02	4.50	1.12E-01	1.50E-01	2.14E+00	2.00E+00	4.23	1.19E-01	7.03E-02	2.18E+00	1.84E+02
8.32	9.82E-02	7.44E-01	1.12E+02	5.80E+02	8.50	9.50E-02	1.75E-01	3.77E+01	3.57E+02	8.30	9.18E-02	6.74E-02	2.50E+00	1.28E+02
24.25	6.14E-02	5.32E-01	2.00E+00	2.40E+02	24.62	7.32E-02	1.17E-01	2.82E+00	1.74E+02	24.12	9.52E-02	9.45E-02	2.78E+00	1.02E+02
48.27	4.57E-02	4.78E-01			48.47	5.65E-02	9.63E-02	3.08E+00	7.80E+01	48.37	8.77E-02	1.92E-01	3.12E+00	1.27E+02
168.12	4.14E-02	3.51E-01	2.00E+00	1.04E+02	95.95	6.16E-02	2.45E-01	3.64E+00	8.45E+01	96.10	1.00E-01	3.03E-01	3.12E+00	1.01E+02
239.82	4.71E-02	3.60E-01	2.27E+01	8.86E+01	168.25	1.33E-01	1.13E-01	4.24E+00	1.01E+02	167.92	1.61E-01	1.27E-01	3.56E+00	1.22E+02

400 mg/L Sludge Solids

214 Time	214 Sr	214 Pu	214 Np	214 U	414 Time	414 Sr	414 Pu	414 Np	414 U	614 Time	614 Sr	614 Pu	614 Np	614 U
0	6.62E+00	6.66E+00	1.08E+03	2.04E+03	0	6.62E+00	7.50E-01	7.82E+02	2.08E+03	0	6.62E+00	7.50E-01	4.72E+02	1.84E+03
2.33	6.15E-02		1.02E+02	8.19E+02	2.33	5.74E-02	1.34E-02	2.22E+01	3.73E+02	2.20	2.46E-01	2.06E-02	2.22E+00	2.71E+02
4.28	3.54E-02	7.29E-02	4.74E+01	4.41E+02	4.32	6.33E-02	1.12E-01	2.14E+00	2.00E+00	4.18	1.41E-01	5.44E-02	2.18E+00	2.24E+02
8.25	2.35E-02	4.31E-01	3.71E+01	3.99E+02	8.30	5.41E-02	3.79E-02	2.66E+00	2.38E+02	8.23	1.05E-01	6.30E-02	2.50E+00	1.70E+02
24.20	2.10E-02	1.79E-01	2.00E+00	2.37E+02	24.45	5.91E-02	2.76E-01	2.82E+00	1.67E+02	24.07	1.14E-01	7.17E-02	2.78E+00	1.26E+02
48.22	2.08E-02	3.19E-02	2.00E+00	2.34E+02	48.30	5.12E-02	9.34E-02	3.08E+00	1.16E+02	48.08	1.29E-01	7.23E-02	2.73E+01	1.49E+02
168.08	3.10E-02	3.91E-02	2.00E+00	1.09E+02	95.80	7.05E-02	2.31E-01	3.64E+00	1.32E+02	96.03	1.68E-01	1.01E-02	2.34E+01	9.52E+01
239.88	2.32E-02	4.49E-02	2.00E+00	8.35E+01	168.12	1.44E-01	8.08E-02	4.24E+00	1.07E+02	167.85	1.81E-01	8.71E-02	3.56E+00	7.48E+01

Appendix 15.
Concentration versus Time Data for Tests at
7.5 M Na⁺, 0.2 g/L MST, Low Activity Solution
(Bottles # 15 and 18)
(Units of Time = hours; Units of Concentration = µg/L)

215 Time	215 Sr	215 Pu	215 Np	215 U	415 Time	415 Sr	415 Pu	415 Np	415 U	615 Time	615 Sr	615 Pu	615 Np	615 U
0	8.28E+00	9.83E+00	1.70E+03	2.56E+03	0	8.28E+00	2.87E+00	9.78E+02	2.60E+03	0	8.28E+00	4.69E-01	5.90E+02	2.30E+03
2.35	3.48E+00	1.15E+01	1.21E+03	2.24E+03	2.35	3.24E+00	4.92E+00	6.96E+02	2.27E+03	2.20	2.32E+00	1.12E+00	2.55E+02	1.90E+03
4.30	2.66E+00	1.03E+01	9.96E+02	2.18E+03	4.35	2.79E+00	5.56E+00	5.83E+02	2.14E+03	4.18	1.94E+00	1.01E+00	2.14E+02	2.00E+03
8.27	2.32E+00	1.09E+01	1.04E+03	2.40E+03	8.35	2.41E+00	5.10E+00	5.96E+02	1.91E+03	8.23	1.60E+00	6.33E-01	1.75E+02	1.60E+03
24.22	1.73E+00	1.02E+01	8.90E+02	2.20E+03	24.47	1.89E+00	4.06E+00	4.98E+02	2.04E+03	24.07	1.71E+00	9.22E-01	1.86E+02	1.55E+03
48.23	1.65E+00	8.18E+00			48.33	1.39E+00	2.16E+00	2.37E+02	1.61E+03	48.12	1.40E+00	5.11E-01	1.39E+02	1.48E+03
168.08	1.40E+00	8.93E+00	5.76E+02	1.91E+03	95.82	1.51E+00	3.77E+00	2.68E+02	1.69E+03	96.03	1.70E+00	4.18E-01	1.59E+02	1.35E+03
239.88	1.34E+00	7.97E+00	5.22E+02	1.90E+03	168.13	2.80E+00	2.52E+00	1.96E+02	1.51E+03	167.85	1.38E+00	3.73E-01	1.83E+02	1.27E+03
218 Time	218 Sr	218 Pu	218 Np	218 U	418 Time	418 Sr	418 Pu	418 Np	418 U	618 Time	618 Sr	618 Pu	618 Np	618 U
0	8.28E+00	9.83E+00	1.70E+03	2.56E+03	0	8.28E+00	2.87E+00	9.78E+02	2.60E+03	0	8.28E+00	4.69E-01	5.90E+02	2.30E+03
2.60	3.63E+00	1.15E+01	1.26E+03	2.55E+03	2.40	3.46E+00	4.76E+00	7.76E+02	2.48E+03	2.25	2.56E+00	1.44E+00	3.02E+02	2.01E+03
4.32	2.67E+00	9.41E+00	1.13E+03	2.39E+03	4.40	2.90E+00	5.69E+00	6.31E+02	2.32E+03	4.22	1.83E+00	9.20E-01	1.80E+02	1.77E+03
8.30	2.38E+00	1.16E+01	1.14E+03	2.50E+03	8.40	2.49E+00	5.81E+00	5.67E+02	1.96E+03	8.28	1.53E+00	3.32E-01	1.92E+02	1.66E+03
24.23	1.85E+00	9.22E+00	8.49E+02	2.24E+03	24.53	2.01E+00	5.09E+00	4.81E+02	2.08E+03	24.10	1.59E+00	1.06E+00	1.86E+02	1.37E+03
48.25	1.67E+00	8.36E+00	2.00E+00	2.00E+00	48.38	1.42E+00	2.83E+00	2.47E+02	1.74E+03	48.17	1.42E+00	5.92E-01	1.51E+02	1.54E+03
168.10	1.44E+00	7.45E+00	5.92E+02	2.07E+03	95.88	1.27E+00	3.04E+00	2.53E+02	1.48E+03	96.08	1.38E+00	5.92E-01	1.36E+02	1.43E+03
239.92	1.39E+00	8.06E+00	4.76E+02	1.78E+03	168.17	3.05E+00	2.85E+00	2.77E+02	1.59E+03	167.90	1.30E+00	5.35E-01	1.58E+02	1.36E+03
Averages of Duplicate Tests - Bottle #15 and #18														
Time	25 Sr	25 Pu	25 Np	25 U	45 Time	45 Sr	45 Pu	45 Np	45 U	65 Time	65 Sr	65 Pu	65 Np	65 U
0	8.28E+00	9.83E+00	1.70E+03	2.56E+03	0	8.28E+00	2.87E+00	9.78E+02	2.60E+03	0	8.28E+00	4.69E-01	5.90E+02	2.30E+03
2.475	3.56E+00	1.15E+01	1.24E+03	2.40E+03	2.375	3.35E+00	4.84E+00	7.36E+02	2.37E+03	2.225	2.44E+00	1.28E+00	2.78E+02	1.96E+03
4.31	2.67E+00	9.86E+00	1.06E+03	2.28E+03	4.375	2.84E+00	5.62E+00	6.07E+02	2.23E+03	4.2	1.89E+00	9.65E-01	1.97E+02	1.89E+03
8.285	2.35E+00	1.13E+01	1.09E+03	2.45E+03	8.375	2.45E+00	5.46E+00	5.82E+02	1.94E+03	8.255	1.56E+00	4.83E-01	1.83E+02	1.63E+03
24.225	1.79E+00	9.69E+00	8.69E+02	2.22E+03	24.5	1.95E+00	4.57E+00	4.89E+02	2.06E+03	24.085	1.65E+00	9.93E-01	1.86E+02	1.46E+03
48.24	1.66E+00	8.27E+00	2.00E+00	2.00E+00	48.355	1.41E+00	2.50E+00	2.42E+02	1.68E+03	48.145	1.41E+00	5.52E-01	1.45E+02	1.51E+03
168.09	1.42E+00	8.19E+00	5.84E+02	1.99E+03	95.85	1.39E+00	3.40E+00	2.60E+02	1.58E+03	96.055	1.54E+00	5.05E-01	1.48E+02	1.39E+03
239.9	1.36E+00	8.01E+00	4.99E+02	1.84E+03	168.15	2.93E+00	2.69E+00	2.36E+02	1.55E+03	167.875	1.34E+00	4.54E-01	1.71E+02	1.32E+03

Appendix 16.
Concentration versus Time Data for Tests at
7.5 M Na⁺, 2.0 g/L MST, Low Activity Solution
(Bottles # 08 and 23)
(Units of Time = hours; Units of Concentration = µg/L)

208 Time	208 Sr	208 Pu	208 Np	208 U	408 Time	408 Sr	408 Pu	408 Np	408 U	608 Time	608 Sr	608 Pu	608 Np	608 U
0	8.28E+00	9.83E+00	1.70E+03	2.37E+03	0	8.28E+00	2.87E+00	9.78E+02	2.60E+03	0	8.28E+00	4.69E-01	5.90E+02	2.30E+03
2.22	1.56E+00	6.57E+00	6.94E+02	1.36E+03	2.18	6.09E-01	2.29E+00	1.84E+02	7.95E+02	2.10	6.68E-01	3.30E-01	4.43E+01	3.03E+02
4.18	6.45E-01	1.58E-02	4.26E+02	6.97E+02	4.18	2.73E-01	1.17E+00	0.00E+00	3.94E+02	4.10	3.59E-01	1.92E-01	3.10E+01	1.80E+02
8.15	4.66E-01	4.96E+00	3.30E+02	7.21E+02	8.18	2.38E-01	2.72E+00	6.67E+01	2.44E+02	8.13	3.07E-01	1.28E-01	2.50E+00	1.37E+02
24.12	2.27E-01	3.48E+00	2.14E+02	3.02E+02	24.32	2.13E-01	7.72E-01	5.58E+01	1.72E+02	24.02	2.55E-01	2.84E-01	2.78E+00	
48.15	1.85E-01	2.09E+00	2.19E+02	2.73E+02	48.18	1.81E-01	5.69E-01	4.65E+01	8.83E+01	48.02	2.35E-01	3.20E-01	1.74E+01	1.26E+02
168.00	1.26E-01	2.04E+00	1.31E+02	1.60E+02	95.67	1.89E-01	5.76E-01	6.57E+01	1.18E+02	95.97	2.34E-01	2.03E-01	3.12E+00	1.13E+02
239.78	1.14E-01	2.31E+00	9.52E+01	1.49E+02	167.98	3.53E-01	1.47E+00	3.91E+01	9.13E+01	167.78	1.36E-01	2.11E-01	3.56E+00	9.71E+01
223 Time	223 Sr	223 Pu	223 Np	223 U	423 Time	423 Sr	423 Pu	423 Np	423 U	623 Time	623 Sr	623 Pu	623 Np	623 U
0	8.28E+00	9.83E+00	1.70E+03	2.37E+03	0	8.28E+00	2.87E+00	9.78E+02	2.60E+03	0	8.28E+00	4.69E-01	5.90E+02	2.30E+03
2.40	1.17E+00	6.47E+00	8.34E+02	1.40E+03	2.55	5.25E-01		1.84E+02	6.10E+02	2.27	7.33E-01	1.55E-02	5.84E+01	4.96E+02
4.35	6.14E-01		4.86E+02	8.56E+02	4.55	3.05E-01	1.67E+00			4.23	4.22E-01	1.71E-01	2.18E+00	3.04E+02
8.37	4.40E-01	5.04E+00	3.56E+02	5.37E+02	8.55	2.53E-01	1.21E+00	7.90E+01	2.39E+02	8.33	3.31E-01	1.63E-01	2.50E+00	1.20E+02
24.30	2.14E-01	2.67E+00	1.63E+02	2.31E+02	24.67	2.16E-01	6.12E-01	1.01E+03	8.22E+02	24.13	3.84E-01	2.27E-01	2.78E+00	1.04E+02
48.30	1.82E-01	2.60E+00			48.52	1.75E-01	2.56E-01	5.41E+01	1.33E+02	48.18	2.16E-01	5.28E-02	1.18E+01	1.04E+02
168.13	1.25E-01	1.32E+00	1.19E+02	1.70E+02	96.02	1.88E-01	5.90E-01	3.87E+01	1.01E+02	96.13	2.79E-01	1.46E-01	3.12E+00	1.12E+02
239.97	1.20E-01	2.17E+00	9.39E+01	1.24E+02	168.28	3.39E-01	5.55E-01	4.85E+01	9.84E+01	167.92	1.77E-01	1.45E-01	3.56E+00	1.21E+02
Averages of Duplicate Tests - Bottle #08 and #23														
Time	25 Sr	25 Pu	25 Np	25 U	45 Time	45 Sr	45 Pu	45 Np	45 U	65 Time	65 Sr	65 Pu	65 Np	65 U
0	8.28E+00	9.83E+00	1.70E+03	2.37E+03	0	8.28E+00	2.87E+00	9.78E+02	2.60E+03	0	8.28E+00	4.69E-01	5.90E+02	2.30E+03
2.31	1.36E+00	6.52E+00	7.64E+02	1.38E+03	2.365	5.67E-01	2.29E+00	1.84E+02	7.03E+02	2.185	7.00E-01	1.73E-01	5.13E+01	3.99E+02
4.265	6.29E-01	1.58E-02	4.56E+02	7.77E+02	4.365	2.89E-01	1.42E+00	0.00E+00	3.94E+02	4.165	3.90E-01	1.82E-01	1.66E+01	2.42E+02
8.26	4.53E-01	5.00E+00	3.43E+02	6.29E+02	8.365	2.46E-01	1.97E+00	7.29E+01	2.42E+02	8.23	3.19E-01	1.45E-01	2.50E+00	1.28E+02
24.21	2.20E-01	3.07E+00	1.88E+02	2.67E+02	24.495	2.15E-01	6.92E-01	5.34E+02	4.97E+02	24.075	3.19E-01	2.55E-01	2.78E+00	1.04E+02
48.225	1.84E-01	2.35E+00	2.19E+02	2.73E+02	48.35	1.78E-01	4.12E-01	5.03E+01	1.10E+02	48.1	2.25E-01	1.86E-01	1.46E+01	1.15E+02
168.065	1.25E-01	1.68E+00	1.25E+02	1.65E+02	95.845	1.89E-01	5.83E-01	5.22E+01	1.09E+02	96.05	2.56E-01	1.74E-01	3.12E+00	1.13E+02
239.875	1.17E-01	2.24E+00	9.45E+01	1.37E+02	168.13	3.46E-01	1.01E+00	4.38E+01	9.48E+01	167.85	1.56E-01	1.78E-01	3.56E+00	1.09E+02

Appendix 17.
Concentration versus Time Data for Tests at
4.5 M Na⁺, 0.2 g/L MST, High Activity Solution
(Bottles # 11 and 31)
 (Units of Time = hours; Units of Concentration = µg/L)

211 Time	211 Sr	211 Pu	211 Np	211 U	411 Time	411 Sr	411 Pu	411 Np	411 U	611 Time	611 Sr	611 Pu	611 Np	611 U
0	6.36E+01	1.68E+02	2.10E+04	1.48E+04	0	5.42E+01	1.61E+02	2.10E+04	1.50E+04	0	6.04E+01	1.60E+02	2.16E+04	1.56E+04
1.98	6.67E-01	9.57E+01	1.89E+04	1.48E+04	2.28	5.15E-01	2.15E+00	1.53E+04	1.32E+04	2.15	6.24E-01	2.15E+00	1.75E+04	1.52E+04
4.17	5.32E-01	2.15E+00	1.46E+04	1.20E+04	4.28	5.32E-01	2.15E+00	1.60E+04	1.32E+04	4.13	5.71E-01	2.15E+00	1.58E+04	1.47E+04
8.10	3.43E-01	5.19E+01	1.85E+04	1.48E+04	8.25	3.60E-01	2.15E+00	1.43E+04	1.24E+04	8.18	5.71E-01	2.15E+00	1.21E+04	1.23E+04
24.10	2.77E-01	2.56E+00	1.41E+04	1.17E+04	24.38	2.87E-01	2.15E+00	1.78E+04	1.59E+04	24.03	5.69E-01	2.15E+00	1.01E+04	1.17E+04
48.13	1.95E-01	2.77E+00	1.66E+04	1.33E+04	48.25	2.85E-01	2.15E+00	1.31E+04	1.23E+04	48.03	5.00E-01	2.15E+00	9.13E+03	1.34E+04
168.33	1.84E-01	3.42E+00	1.52E+04	1.28E+04	95.75	2.41E-01	2.15E+00	1.31E+04	1.32E+04	96.00	4.90E-01	2.15E+00	8.87E+03	1.26E+04
239.40					168.08	2.70E-01	2.15E+00	1.01E+04	1.21E+04	167.82	5.52E-01	2.15E+00	7.17E+03	1.16E+04
231 Time	231 Sr	231 Pu	231 Np	231 U	431 Time	431 Sr	431 Pu	431 Np	431 U	631 Time	631 Sr	631 Pu	631 Np	631 U
0	6.36E+01	1.68E+02	2.10E+04	1.48E+04	0	5.42E+01	1.61E+02	2.10E+04	1.50E+04	0	6.04E+01	1.60E+02	2.16E+04	1.56E+04
2.13	7.00E-01	7.61E+01	1.85E+04	1.41E+04	2.77	4.73E-01	2.15E+00	1.46E+04	1.25E+04	2.32	7.14E-01	2.15E+00		
4.30	4.07E-01	5.31E+01	1.82E+04	1.54E+04	4.75	4.01E-01	2.15E+00	1.50E+04	1.24E+04	4.27	5.14E-01	2.15E+00	1.65E+04	1.47E+04
8.22	3.30E-01	2.62E+00	1.90E+04	1.52E+04	8.73	4.23E-01	2.15E+00	1.64E+04	1.39E+04	7.37	5.51E-01	2.62E+00	1.33E+04	1.37E+04
24.20	2.91E-01	2.56E+00	1.63E+04	1.30E+04	24.85	3.54E-01	2.15E+00	1.83E+04	1.57E+04	24.17	4.29E-01	2.56E+00	9.58E+03	1.13E+04
48.22	2.74E-01	2.77E+00	1.64E+04	1.34E+04	48.68	3.38E-01	2.15E+00	1.48E+04	1.39E+04	48.28	5.30E-01	1.68E+01	8.48E+03	1.27E+04
168.43	3.03E-01	3.42E+00	1.57E+04	1.28E+04	96.18	2.99E-01	2.15E+00	1.47E+04	1.44E+04	96.17	5.95E-01	3.42E+00	8.77E+03	1.28E+04
239.47	1.65E-01	4.05E+00	1.41E+04	1.19E+04	168.45	2.85E-01	2.15E+00	1.07E+04	1.19E+04	167.93	4.62E-01	4.05E+00	7.09E+03	1.13E+04
Averages of Duplicate Tests - Bottle #11 and #31														
Time	25 Sr	25 Pu	25 Np	25 U	45 Time	45 Sr	45 Pu	45 Np	45 U	65 Time	65 Sr	65 Pu	65 Np	65 U
0	6.36E+01	1.68E+02	2.10E+04	1.48E+04	0	5.42E+01	1.61E+02	2.10E+04	1.50E+04	0	6.04E+01	1.60E+02	2.16E+04	1.56E+04
2.055	6.83E-01	8.59E+01	1.87E+04	1.45E+04	2.525	4.94E-01	2.15E+00	1.50E+04	1.28E+04	2.235	6.69E-01	2.15E+00	1.75E+04	1.52E+04
4.235	4.70E-01	2.76E+01	1.64E+04	1.37E+04	4.515	4.66E-01	2.15E+00	1.55E+04	1.28E+04	4.2	5.43E-01	2.15E+00	1.62E+04	1.47E+04
8.16	3.37E-01	2.72E+01	1.87E+04	1.50E+04	8.49	3.91E-01	2.15E+00	1.54E+04	1.31E+04	7.775	5.61E-01	2.38E+00	1.27E+04	1.30E+04
24.15	2.84E-01	2.56E+00	1.52E+04	1.23E+04	24.615	3.20E-01	2.15E+00	1.81E+04	1.58E+04	24.1	4.99E-01	2.35E+00	9.86E+03	1.15E+04
48.175	2.35E-01	2.77E+00	1.65E+04	1.33E+04	48.465	3.11E-01	2.15E+00	1.39E+04	1.31E+04	48.155	5.15E-01	9.50E+00	8.80E+03	1.30E+04
168.38	2.44E-01	3.42E+00	1.54E+04	1.28E+04	95.965	2.70E-01	2.15E+00	1.39E+04	1.38E+04	96.085	5.42E-01	2.78E+00	8.82E+03	1.27E+04
239.435	1.65E-01	4.05E+00	1.41E+04	1.19E+04	168.265	2.78E-01	2.15E+00	1.04E+04	1.20E+04	167.875	5.07E-01	3.10E+00	7.13E+03	1.15E+04

Appendix 18.
Concentration versus Time Data for Tests at
4.5 M Na⁺, 2.0 g/L MST, High Activity Solution
(Bottles # 20 and 29)
(Units of Time = hours; Units of Concentration = µg/L)

220 Time	220 Sr	220 Pu	220 Np	220 U	420 Time	420 Sr	420 Pu	420 Np	420 U	620 Time	620 Sr	620 Pu	620 Np	620 U
0	6.36E+01	1.68E+02	2.10E+04	1.48E+04	0	5.42E+01	1.61E+02	2.10E+04	1.50E+04	0	6.04E+01	1.60E+02	2.16E+04	1.56E+04
2.03	1.84E-03	2.15E+00	1.50E+04	9.65E+03	2.47	3.19E-03	2.15E+00	1.23E+04	6.88E+03	2.27	6.77E-03	2.15E+00	1.04E+04	5.89E+03
4.23	2.87E-03	1.94E+01	1.47E+04	8.32E+03	4.47	3.06E-03	2.15E+00	1.14E+04	5.39E+03	4.25	3.16E-03	2.15E+00	1.07E+04	4.45E+03
8.17	2.91E-03	2.62E+00	1.53E+04	7.83E+03	8.45	5.30E-02	2.15E+00	1.16E+04	4.60E+03	8.32	8.40E-03	2.15E+00	8.31E+03	3.15E+03
24.15	2.78E-03	2.56E+00	1.23E+04	5.33E+03	24.58	3.18E-03	2.15E+00	1.18E+04	2.96E+03	24.12	4.15E-02	2.15E+00	4.43E+03	2.07E+03
48.17	3.15E-02	2.77E+00	1.24E+04	4.14E+03	48.43	3.23E-03	2.15E+00	8.10E+03	1.76E+03	48.20	7.10E-02	2.15E+00	9.56E+02	1.86E+03
168.38	3.15E-03	3.42E+00	1.03E+04	2.29E+03	95.93	3.25E-03	2.15E+00	7.35E+03	1.64E+03	96.10	5.59E-02	2.15E+00	3.17E+02	1.72E+03
239.43	3.38E-03	4.05E+00	9.31E+03	1.91E+03	168.23	3.15E-02	2.15E+00	4.37E+03	1.19E+03	167.93	3.35E-03	2.15E+00	2.89E+02	1.73E+03
229 Time	229 Sr	229 Pu	229 Np	229 U	429 Time	429 Sr	429 Pu	429 Np	429 U	629 Time	629 Sr	629 Pu	629 Np	629 U
0	6.36E+01	1.68E+02	2.10E+04	1.48E+04	0	5.42E+01	1.61E+02	2.10E+04	1.50E+04	0	6.04E+01	1.60E+02	2.16E+04	1.56E+04
2.12	5.51E-02	2.15E+00	1.53E+04	1.00E+04	2.70	3.21E-03	2.15E+00	1.19E+04	7.10E+03	2.32	4.52E-03	2.15E+00	1.06E+04	6.06E+03
4.28	2.90E-03	1.92E+01	1.80E+04	1.00E+04	4.70	2.85E-03	2.15E+00	1.21E+04	5.70E+03	4.27	9.36E-04	2.15E+00	1.06E+04	4.41E+03
8.20	2.91E-03	2.62E+00	1.55E+04	7.98E+03	8.68	5.72E-02	2.15E+00	1.15E+04	4.79E+03	7.38	3.35E-02	2.15E+00	8.52E+03	3.29E+03
24.18	3.29E-03	2.56E+00	1.25E+04	5.61E+03	24.80	3.18E-03	2.15E+00	1.24E+04	3.29E+03	24.17	9.37E-02	2.15E+00	4.54E+03	1.96E+03
48.20	2.95E-03	2.77E+00	1.21E+04	4.34E+03	48.63	4.47E-02	2.15E+00	8.24E+03	1.91E+03	48.27	4.80E-03	2.15E+00	9.74E+02	1.96E+03
168.42	3.15E-03	3.42E+00	1.04E+04	2.45E+03	96.15	3.25E-03	2.15E+00	8.01E+03	1.88E+03	96.17	5.43E-02	2.15E+00	3.06E+02	1.77E+03
239.47	3.38E-03	4.05E+00	8.96E+03	1.87E+03	168.42	4.68E-02	2.15E+00	3.92E+03	1.11E+03	167.95	3.35E-03	2.15E+00	2.34E+02	1.41E+03
Averages of Duplicate Tests - Bottle #20 and #29														
Time	25 Sr	25 Pu	25 Np	25 U	45 Time	45 Sr	45 Pu	45 Np	45 U	65 Time	65 Sr	65 Pu	65 Np	65 U
0	6.36E+01	1.68E+02	2.10E+04	1.48E+04	0	5.42E+01	1.61E+02	2.10E+04	1.50E+04	0	60.4	1.60E+02	2.16E+04	1.56E+04
2.075	2.84E-02	2.15E+00	1.52E+04	9.83E+03	2.585	3.20E-03	2.15E+00	1.21E+04	6.99E+03	2.295	0.0056417	2.15E+00	1.05E+04	5.98E+03
4.255	2.89E-03	1.93E+01	1.63E+04	9.17E+03	4.585	2.95E-03	2.15E+00	1.17E+04	5.55E+03	4.26	0.0020466	2.15E+00	1.07E+04	4.43E+03
8.185	2.91E-03	2.62E+00	1.54E+04	7.91E+03	8.565	5.51E-02	2.15E+00	1.15E+04	4.70E+03	7.85	0.020954	2.15E+00	8.42E+03	3.22E+03
24.165	3.04E-03	2.56E+00	1.24E+04	5.47E+03	24.69	3.18E-03	2.15E+00	1.21E+04	3.13E+03	24.145	0.0676066	2.15E+00	4.49E+03	2.01E+03
48.185	1.72E-02	2.77E+00	1.22E+04	4.24E+03	48.53	2.39E-02	2.15E+00	8.17E+03	1.83E+03	48.235	0.0378849	2.15E+00	9.65E+02	1.91E+03
168.4	3.15E-03	3.42E+00	1.04E+04	2.37E+03	96.04	3.25E-03	2.15E+00	7.68E+03	1.76E+03	96.135	0.0551141	2.15E+00	3.12E+02	1.74E+03
239.45	3.38E-03	4.05E+00	9.14E+03	1.89E+03	168.325	3.92E-02	2.15E+00	4.15E+03	1.15E+03	167.94	0.0033484	2.15E+00	2.61E+02	1.57E+03

Appendix 19.
Concentration versus Time Data for Tests at
6.0 M Na⁺, 1.1 g/L MST, High Activity Solution
(Bottles # 07 and 32)
(Units of Time = hours; Units of Concentration = µg/L)

207 Time	207 Sr	207 Pu	207 Np	207 U	407 Time	407 Sr	407 Pu	407 Np	407 U	607 Time	607 Sr	607 Pu	607 Np	607 U
0	8.48E+01	2.23E+02	2.80E+04	1.97E+04	0	7.22E+01	2.14E+02	2.78E+04	2.00E+04	0	8.02E+01	2.13E+02	2.86E+04	2.08E+04
1.97	1.06E-01	8.03E+01	2.29E+04	1.67E+04	2.15	1.47E-02	2.15E+00	1.78E+04	1.40E+04	2.08	1.08E-01	2.01E+01	2.05E+04	1.48E+04
4.15	3.10E-02	2.15E+00	1.80E+04	1.36E+04	4.17	7.52E-02	2.15E+00	1.78E+04	1.23E+04	4.10	1.10E-01	2.15E+00	1.77E+04	1.15E+04
8.08	6.81E-02	4.38E+01	2.10E+04	1.54E+04	8.15	3.19E-02	2.15E+00	1.48E+04	9.01E+03	8.12	1.16E-01	2.15E+00	1.34E+04	8.99E+03
24.08		3.41E+01	1.88E+04	1.21E+04	24.28	7.51E-02	2.15E+00	1.85E+04	9.82E+03	24.00	8.32E-02	2.15E+00	9.53E+03	7.75E+03
48.12	1.35E-02	2.44E+01	1.93E+04	1.11E+04	48.17	3.68E-02	2.15E+00	1.66E+03	8.89E+03	48.00	8.61E-02	2.15E+00	5.20E+03	8.28E+03
168.32	4.03E-02	2.15E+00	1.74E+04	8.31E+03	95.60	4.16E-02	2.15E+00	1.18E+04	6.72E+03	95.97	3.56E-02	2.15E+00	2.77E+03	8.67E+03
239.38	5.81E-02	2.15E+00	1.59E+04	7.18E+03	167.97	3.49E-02	2.15E+00	9.71E+03	7.15E+03	167.77	4.14E-02	2.15E+00	2.13E+03	7.36E+03
232 Time	232 Sr	232 Pu	232 Np	232 U	432 Time	432 Sr	432 Pu	432 Np	432 U	632 Time	632 Sr	632 Pu	632 Np	632 U
0	8.48E+01	2.23E+02	2.80E+04	1.97E+04	0	7.22E+01	2.14E+02	2.78E+04	2.00E+04	0	8.02E+01	2.13E+02	2.86E+04	2.08E+04
2.15	8.03E-02	4.84E+01	2.17E+04	1.67E+04	2.78	7.79E-02	2.15E+00	1.79E+04	1.29E+04	2.33	8.13E-02	2.15E+00	1.69E+04	1.25E+04
4.32	8.47E-02	4.15E+01	2.26E+04	1.59E+04	4.77	6.39E-02	2.15E+00	1.74E+04	1.16E+04	4.28	1.14E-01	2.15E+00	1.79E+04	1.21E+04
8.23	1.72E-01	3.56E+01	2.28E+04	1.64E+04	8.75	5.96E-02	2.15E+00	1.83E+04	1.15E+04	7.40	6.86E-02	2.15E+00	1.45E+04	1.02E+04
24.20	1.31E-01	2.15E+00	1.89E+04	1.20E+04	24.88	4.15E-02	2.15E+00	2.03E+04	1.03E+04	24.18	6.56E-02	2.15E+00	8.99E+03	7.64E+03
48.23	3.84E-03	2.15E+00	1.95E+04	1.09E+04	48.72	5.26E-02	2.15E+00	1.53E+04	7.27E+03	48.30	9.13E-02	2.15E+00	5.01E+03	8.12E+03
168.45	3.94E-02	2.15E+00	1.81E+04	8.41E+03	96.22	2.95E-02	2.15E+00	1.60E+04	8.27E+03	96.17	7.21E-02	2.15E+00	2.96E+03	9.11E+03
239.48					168.50	2.96E-02	2.15E+00	1.13E+04	6.47E+03	167.95	3.34E-03	2.15E+00	2.04E+03	7.31E+03
Averages of Duplicate Tests - Bottle #7 and #32														
Time	25 Sr	25 Pu	25 Np	25 U	45 Time	45 Sr	45 Pu	45 Np	45 U	65 Time	65 Sr	65 Pu	65 Np	65 U
0	8.48E+01	2.23E+02	2.80E+04	1.97E+04	0	7.22E+01	2.14E+02	2.78E+04	2.00E+04	0	8.02E+01	2.13E+02	2.86E+04	2.08E+04
2.06	9.34E-02	6.44E+01	2.23E+04	1.67E+04	2.465	4.63E-02	2.15E+00	1.78E+04	1.35E+04	2.205	9.45E-02	1.11E+01	1.87E+04	1.36E+04
4.235	5.79E-02	2.18E+01	2.03E+04	1.48E+04	4.47	6.95E-02	2.15E+00	1.76E+04	1.19E+04	4.19	1.12E-01	2.15E+00	1.78E+04	1.18E+04
8.155	1.20E-01	3.97E+01	2.19E+04	1.59E+04	8.45	4.58E-02	2.15E+00	1.65E+04	1.02E+04	7.76	9.21E-02	2.15E+00	1.39E+04	9.58E+03
24.14	1.31E-01	1.81E+01	1.88E+04	1.21E+04	24.58	5.83E-02	2.15E+00	1.94E+04	1.00E+04	24.09	7.44E-02	2.15E+00	9.26E+03	7.70E+03
48.175	8.68E-03	1.33E+01	1.94E+04	1.10E+04	48.445	4.47E-02	2.15E+00	8.48E+03	8.08E+03	48.15	8.87E-02	2.15E+00	5.10E+03	8.20E+03
168.385	3.98E-02	2.15E+00	1.78E+04	8.36E+03	95.91	3.56E-02	2.15E+00	1.39E+04	7.50E+03	96.07	5.39E-02	2.15E+00	2.86E+03	8.89E+03
239.43	5.81E-02	2.15E+00	1.59E+04	7.18E+03	168.235	3.22E-02	2.15E+00	1.05E+04	6.81E+03	167.86	2.24E-02	2.15E+00	2.08E+03	7.34E+03

Appendix 20.
Concentration versus Time Data for Tests at
6.0 M Na⁺, 1.1 g/L MST, High Activity Solution, No Mixing
(Bottles # 03 and 13)
(Units of Time = hours; Units of Concentration = µg/L)

203 Time	203 Sr	203 Pu	203 Np	203 U	403 Time	403 Sr	403 Pu	403 Np	403 U	603 Time	603 Sr	603 Pu	603 Np	603 U
0	8.48E+01	2.23E+02	2.80E+04	1.97E+04	0	7.22E+01	2.14E+02	2.78E+04	2.00E+04	0	8.02E+01	2.13E+02	2.86E+04	2.08E+04
2.20	1.77E-01	4.48E+01	2.28E+04	1.70E+04	2.82	1.04E-01	2.15E+00	1.9148.06	1.41E+04	2.05	2.09E-01	1.87E+01	2.10E+04	1.51E+04
4.28	2.93E-02	2.15E+00	1.87E+04	1.40E+04	4.80	4.95E-02	2.15E+00	1.9058.44	1.22E+04	4.00	6.84E-02	2.15E+00	1.72E+04	1.21E+04
8.27	4.77E-02	2.15E+00	2.17E+04	1.51E+04	8.80	8.38E-02	2.15E+00	1.8081.66	1.17E+04	8.02	1.26E-01	2.15E+00	1.34E+04	9.45E+03
24.22	1.11E-01	2.15E+00	1.76E+04	1.15E+04	24.97	1.38E-01	2.15E+00	1.8232.46	9.99E+03	24.12	6.79E-02	2.15E+00	9.49E+03	8.20E+03
48.25	3.38E-02	2.49E+01	1.98E+04	1.19E+04	48.77	1.16E-01	2.15E+00	1.6825.12	8.83E+03	48.05	7.58E-02	2.15E+00	5.24E+03	8.20E+03
168.48	1.88E-01	2.15E+00	1.85E+04	9.20E+03	96.28	1.03E-01	2.15E+00	1.3988.54	7.46E+03	95.98	7.08E-02	2.15E+00	2.85E+03	8.12E+03
239.55	9.15E-02	2.15E+00	1.73E+04	8.02E+03	168.58	5.95E-02	2.15E+00	1.1736.68	7.19E+03	167.82	7.55E-02	2.15E+00	2.15E+03	7.68E+03
213 Time	213 Sr	213 Pu	213 Np	213 U	413 Time	413 Sr	413 Pu	413 Np	413 U	613 Time	613 Sr	613 Pu	613 Np	613 U
0	8.48E+01	2.23E+02	2.80E+04	1.97E+04	0	7.22E+01	2.14E+02	2.78E+04	2.00E+04	0	8.02E+01	2.13E+02	2.86E+04	2.08E+04
2.22	1.13E-01	4.71E+01	2.22E+04	1.63E+04	2.85	1.21E-01	2.15E+00	1.75E+04	1.32E+04	2.07	1.00E-01	2.15E+00	1.92E+04	1.42E+04
4.23	2.15E+00	1.76E+04	1.30E+04	1.30E+04	4.83	7.14E-02	2.15E+00	1.80E+04	1.17E+04	4.03	2.17E-01	2.15E+00	1.71E+04	1.19E+04
8.28	4.75E-02	2.15E+00	2.34E+04	1.57E+04	8.83	8.73E-02	2.15E+00	1.60E+04	1.05E+04	8.03	1.41E-01	2.15E+00	1.35E+04	9.29E+03
24.23	3.09E+01	1.68E+04	1.12E+04	1.12E+04	24.98	1.17E-01	2.15E+00	1.92E+04	1.09E+04	24.12	1.50E-01	2.15E+00	9.48E+03	7.77E+03
48.28	2.30E-02	2.41E+01	1.81E+04	1.06E+04	48.78	1.03E-01	2.15E+00	1.50E+04	8.36E+03	48.07	1.03E-01	2.15E+00	5.74E+03	8.43E+03
168.50	1.04E-01	2.15E+00	1.86E+04	9.01E+03	96.32	6.31E-02	2.15E+00	1.44E+04	8.03E+03	95.98	3.22E-02	2.15E+00	2.95E+03	8.32E+03
239.55					168.60	6.25E-02	2.15E+00	1.11E+04	7.11E+03	167.83	6.78E-02	2.15E+00	1.88E+03	7.55E+03
Averages of Duplicate Tests - Bottle #3 and #13														
Time	25 Sr	25 Pu	25 Np	25 U	45 Time	45 Sr	45 Pu	45 Np	45 U	65 Time	65 Sr	65 Pu	65 Np	65 U
0	8.48E+01	2.23E+02	2.80E+04	1.97E+04	0	7.22E+01	2.14E+02	2.78E+04	2.00E+04	0	8.02E+01	2.13E+02	2.86E+04	2.08E+04
2.21	1.45E-01	4.60E+01	2.25E+04	1.66E+04	2.835	1.13E-01	2.15E+00	1.83E+04	1.36E+04	2.06	1.55E-01	1.04E+01	2.01E+04	1.47E+04
4.255	2.93E-02	2.15E+00	1.81E+04	1.35E+04	4.815	6.05E-02	2.15E+00	1.85E+04	1.20E+04	4.015	1.43E-01	2.15E+00	1.71E+04	1.20E+04
8.275	4.76E-02	2.15E+00	2.26E+04	1.54E+04	8.815	8.55E-02	2.15E+00	1.71E+04	1.11E+04	8.025	1.33E-01	2.15E+00	1.35E+04	9.37E+03
24.225	1.11E-01	1.65E+01	1.72E+04	1.13E+04	24.975	1.28E-01	2.15E+00	1.87E+04	1.05E+04	24.12	1.09E-01	2.15E+00	9.49E+03	7.99E+03
48.265	2.84E-02	2.45E+01	1.90E+04	1.12E+04	48.775	1.10E-01	2.15E+00	1.59E+04	8.60E+03	48.06	8.94E-02	2.15E+00	5.49E+03	8.32E+03
168.49	1.46E-01	2.15E+00	1.85E+04	9.10E+03	96.3	8.31E-02	2.15E+00	1.42E+04	7.74E+03	95.98	5.15E-02	2.15E+00	2.90E+03	8.22E+03
239.55	9.15E-02	2.15E+00	1.73E+04	8.02E+03	168.59	6.10E-02	2.15E+00	1.14E+04	7.15E+03	167.825	7.17E-02	2.15E+00	2.02E+03	7.61E+03

Appendix 21.
Concentration versus Time Data for Tests at
6.0 M Na⁺, 1.1 g/L MST, High Activity Solution, NaTPB or Sludge Added
(Bottles # 05 and 19)

(Units of Time = hours; Units of Concentration = µg/L)

400 mg/L NaTPB

205 Time	205 Sr	205 Pu	205 Np	205 U	405 Time	405 Sr	405 Pu	405 Np	405 U	605 Time	605 Sr	605 Pu	605 Np	605 U
0	8.48E+01	2.23E+02	2.80E+04	1.97E+04	0	7.22E+01	2.14E+02	27800	2.00E+04	0	8.02E+01	2.13E+02	2.86E+04	2.08E+04
1.92	2.20E-01	5.50E+01	2.23E+04	1.65E+04	2.10	1.16E-01	2.15E+00	18602.38	1.44E+04	2.05	2.09E-01	2.15E+00	2.09E+04	1.46E+04
4.08	5.41E-02	2.15E+00	1.84E+04	1.41E+04	4.10	4.91E-02	2.15E+00	17783.98	1.24E+04	4.05	1.29E-01	2.15E+00	1.73E+04	1.14E+04
8.03	7.69E-02	5.66E+01	2.19E+04	1.52E+04	8.10	1.04E-01	2.15E+00	16580.16	1.08E+04	8.10	8.87E-02	2.15E+00	1.36E+04	8.97E+03
24.03	1.60E-02	2.15E+00	1.75E+04	1.14E+04	24.23	1.09E-01	2.15E+00	17901.56	9.51E+03	23.97	1.76E-01	2.15E+00	9.34E+03	7.78E+03
48.07	1.60E-02	2.15E+00	1.89E+04	1.09E+04	48.12	6.12E-02	2.15E+00	16847.3	9.05E+03	47.97	1.19E-01	2.15E+00	4.96E+03	8.32E+03
168.28	1.72E-02	2.15E+00	1.83E+04	8.58E+03	95.57	7.28E-02	2.15E+00	12107.96	7.21E+03	65.93	9.43E-02	2.15E+00	2.72E+03	8.67E+03
239.35	1.10E-01	2.15E+00	1.59E+04	7.28E+03	167.93	5.10E-02	2.15E+00	9570.76	7.23E+03	167.67	9.54E-02	2.15E+00	2.09E+03	7.18E+03

400 mg/L Sludge Solids

219 Time	219 Sr	219 Pu	219 Np	219 U	419 Time	419 Sr	419 Pu	419 Np	419 U	619 Time	619 Sr	619 Pu	619 Np	619 U
0	8.48E+01	2.23E+02	2.80E+04	1.97E+04	0	7.22E+01	2.14E+02	2.78E+04	2.00E+04	0	8.02E+01	2.13E+02	2.86E+04	2.08E+04
2.02	4.49E-01	5.90E+01	2.19E+04	1.64E+04	2.43	2.05E-01	2.15E+00	1.79E+04	1.26E+04	2.27	1.80E-01	2.15E+00	1.65E+04	1.31E+04
4.22	1.90E-01	2.15E+00	2.25E+04	1.68E+04	4.43	1.30E-01	2.15E+00	1.74E+04	1.22E+04	4.23	2.58E-01	2.15E+00	1.41E+04	1.20E+04
8.15	1.42E-01	2.15E+00	2.21E+04	1.56E+04	8.43	1.68E-01	2.15E+00	1.83E+04	1.20E+04	8.30	1.73E-01	2.15E+00	1.07E+04	1.06E+04
23.97	1.96E-01	2.15E+00	1.82E+04	1.28E+04	24.55	1.87E-01	2.15E+00	2.03E+04	1.17E+04	24.10	1.94E-01	2.15E+00	6.26E+03	9.02E+03
48.15	1.62E-01	2.15E+00	1.73E+04	1.20E+04	48.40	1.52E-01	2.15E+00	1.53E+04	9.46E+03	48.18	2.90E-03	6.32E+00	4.92E+03	9.69E+03
168.35	5.84E-02	2.15E+00	1.46E+04	9.75E+03	95.92	1.04E-01	2.15E+00	1.60E+04	9.88E+03	96.10	1.55E-01	2.15E+00	5.11E+03	1.00E+04
239.42	9.28E-02	2.15E+00	1.32E+04	9.15E+03	168.20	1.05E-01	2.15E+00	1.13E+04	8.22E+03	167.92	1.43E-01	2.15E+00	4.52E+03	8.89E+03

Appendix 22.
Concentration versus Time Data for Tests at
7.5 M Na⁺, 0.2 g/L MST, High Activity Solution
(Bottles # 01 and 28)
(Units of Time = hours; Units of Concentration = µg/L)

201 Time	201 Sr	201 Pu	201 Np	201 U	401 Time	401 Sr	401 Pu	401 Np	401 U	601 Time	601 Sr	601 Pu	601 Np	601 U
0	1.06E+02	2.80E+02	3.50E+04	2.46E+04	0	9.02E+01	2.69E+02	3.48E+04	2.50E+04	0	1.00E+02	2.67E+02	3.58E+04	2.60E+04
1.88	3.51E+00	2.45E+02	3.62E+04	2.76E+04	2.02	2.44E+00	1.15E+02	2.96E+04	2.57E+04	1.98	2.91E+00	5.24E+01	3.71E+04	
4.02	1.88E+00	2.05E+02	3.00E+04	2.41E+04	4.02	1.98E+00	2.15E+00	2.75E+04	2.22E+04	4.00	2.54E+00	2.15E+00	2.79E+04	2.42E+04
8.00	1.49E+00	1.59E+02	3.00E+04	2.39E+04	8.02	1.74E+00	3.29E+01	2.29E+04	2.04E+04	8.03	2.52E+00	2.15E+00	2.22E+04	2.14E+04
23.98	1.40E+00	6.62E+01	2.42E+04	1.84E+04	24.12	1.59E+00	2.15E+00	2.44E+04	2.11E+04	23.92	2.41E+00	2.15E+00	1.89E+04	1.99E+04
47.98	1.30E+00	4.60E+01	2.43E+04	1.76E+04	48.02	7.07E-01	2.15E+00	2.26E+04	2.12E+04	47.92	2.48E+00	7.91E+00	1.63E+04	1.94E+04
168.25	1.17E+00	3.42E+00	2.27E+04	1.52E+04	95.47	1.35E+00	2.15E+00	1.92E+04	1.86E+04	95.92	2.38E+00	2.15E+00	1.46E+04	1.90E+04
239.33	1.33E+00	4.05E+00	2.11E+04	1.51E+04	167.83	1.57E+00	2.15E+00	1.64E+04	1.69E+04	167.60	2.29E+00	2.15E+00	1.12E+04	1.56E+04
228 Time	228 Sr	228 Pu	228 Np	228 U	428 Time	428 Sr	428 Pu	428 Np	428 U	628 Time	628 Sr	628 Pu	628 Np	628 U
0	1.06E+02	2.80E+02	3.50E+04	2.46E+04	0	9.02E+01	2.69E+02	3.48E+04	2.50E+04	0	1.00E+02	2.67E+02	3.58E+04	2.60E+04
2.10	2.21E+00	1.87E+02	2.92E+04	2.12E+04	2.67	2.18E+00	9.59E+01	2.43E+04	2.27E+04	2.30	2.31E+00	5.52E+01		
4.27	1.86E+00	1.93E+02	3.78E+04	2.93E+04	4.67	1.79E+00	2.15E+00	2.49E+04	2.03E+04	4.27	2.32E+00	2.15E+00	3.02E+04	2.60E+04
8.20	1.58E+00	1.35E+02	3.02E+04	2.34E+04	8.67	1.83E+00	4.36E+01	2.41E+04	2.09E+04	7.37	2.33E+00	2.15E+00	2.47E+04	2.26E+04
24.18	1.37E+00	2.56E+00	2.48E+04	1.84E+04	24.78	1.51E+00	2.15E+00	2.68E+04	2.36E+04	24.15	2.26E+00	2.15E+00	1.83E+04	1.91E+04
48.20	1.22E+00	5.21E+01	2.37E+04	1.65E+04	48.62	1.59E+00	2.15E+00	1.97E+04	1.88E+04	48.25	2.05E+00	5.31E+00	1.57E+04	1.83E+04
168.40	1.29E+00	3.42E+00	2.30E+04	1.58E+04	96.13	1.33E+00	2.15E+00	2.00E+04	1.98E+04	96.15	2.39E+00	2.15E+00	1.45E+04	1.89E+04
238.58	1.34E+00	4.05E+00	1.95E+04	1.36E+04	168.40	1.43E+00	2.15E+00	1.54E+04	1.57E+04	167.93	2.13E+00	2.15E+00	1.28E+04	1.72E+04
Averages of Duplicate Tests - Bottle #01 and #28														
Time	25 Sr	25 Pu	25 Np	25 U	45 Time	45 Sr	45 Pu	45 Np	45 U	65 Time	65 Sr	65 Pu	65 Np	65 U
0	1.06E+02	2.80E+02	3.50E+04	2.46E+04	0	9.02E+01	2.69E+02	3.48E+04	2.50E+04	0	1.00E+02	2.67E+02	3.58E+04	2.60E+04
1.99	2.86E+00	2.16E+02	3.27E+04	2.44E+04	2.345	2.31E+00	1.06E+02	2.69E+04	2.42E+04	2.14	2.61E+00	5.38E+01	3.71E+04	
4.145	1.87E+00	1.99E+02	3.39E+04	2.67E+04	4.345	1.88E+00	2.15E+00	2.62E+04	2.13E+04	4.135	2.43E+00	2.15E+00	2.91E+04	2.51E+04
8.1	1.54E+00	1.47E+02	3.01E+04	2.36E+04	8.345	1.78E+00	3.83E+01	2.35E+04	2.07E+04	7.7	2.43E+00	2.15E+00	2.34E+04	2.20E+04
24.08	1.38E+00	3.44E+01	2.45E+04	1.84E+04	24.45	1.55E+00	2.15E+00	2.56E+04	2.23E+04	24.035	2.34E+00	2.15E+00	1.86E+04	1.95E+04
48.09	1.26E+00	4.91E+01	2.40E+04	1.71E+04	48.32	1.15E+00	2.15E+00	2.12E+04	2.00E+04	48.085	2.26E+00	6.61E+00	1.60E+04	1.89E+04
168.325	1.23E+00	3.42E+00	2.29E+04	1.55E+04	95.8	1.34E+00	2.15E+00	1.96E+04	1.92E+04	96.035	2.39E+00	2.15E+00	1.45E+04	1.90E+04
238.955	1.33E+00	4.05E+00	2.03E+04	1.43E+04	168.115	1.50E+00	2.15E+00	1.59E+04	1.63E+04	167.765	2.21E+00	2.15E+00	1.20E+04	1.64E+04

Appendix 23.
Concentration versus Time Data for Tests at
7.5M Na⁺, 2.0 g/L MST, High Activity Solution
(Bottles # 17 and 27)
(Units of Time = hours; Units of Concentration = µg/L)

217 Time	217 Sr	217 Pu	217 Np	217 U	417 Time	417 Sr	417 Pu	417 Np	417 U	617 Time	617 Sr	617 Pu	617 Np	617 U
0	1.06E+02	2.80E+02	3.50E+04	2.46E+04	0	9.02E+01	2.69E+02	3.48E+04	2.50E+04	0	1.00E+02	2.67E+02	3.58E+04	2.60E+04
2.00	2.56E-01	6.14E+01	2.91E+04	2.05E+04	2.37	1.01E-01	4.17E+01	2.21E+04	1.57E+04	2.22	3.57E-02	2.15E+00	2.15E+04	1.33E+04
4.20	7.02E-02	5.54E+01	2.99E+04	1.98E+04	4.37	9.03E-02	2.15E+00	2.02E+04	1.22E+04	4.18	1.52E-01	2.15E+00	2.01E+04	1.03E+04
8.12	5.44E-02	2.62E+00	2.77E+04	1.67E+04	8.37	1.19E-01	2.15E+00	2.12E+04	1.11E+04	8.25	1.02E-01	2.15E+00	1.65E+04	8.19E+03
24.12	1.81E-01	2.56E+00	2.28E+04	1.23E+04	24.50	2.40E-01	2.15E+00	2.16E+04	8.08E+03	24.07	1.11E-01	2.15E+00	1.09E+04	5.82E+03
48.15	6.32E-02	3.41E+01	2.24E+04	9.24E+03	48.37	1.97E-01	2.15E+00	1.74E+04	5.64E+03	48.47	1.69E-01	2.15E+00	5.77E+03	5.97E+03
168.35	1.32E-01	3.42E+00	2.11E+04	6.18E+03	95.85	5.67E-02	2.15E+00	1.32E+04	4.53E+03	96.05	8.33E-02	2.15E+00	2.30E+03	6.49E+03
239.42	2.60E-01	4.05E+00	1.78E+04	4.77E+03	168.15	7.12E-02	2.15E+00	9.49E+03	3.77E+03	167.87	4.78E-02	2.15E+00	1.92E+03	5.78E+03
227 Time	227 Sr	227 Pu	227 Np	227 U	427 Time	427 Sr	427 Pu	427 Np	427 U	627 Time	627 Sr	627 Pu	627 Np	627 U
0	1.06E+02	2.80E+02	3.50E+04	2.46E+04	0	9.02E+01	2.69E+02	3.48E+04	2.50E+04	0	1.00E+02	2.67E+02	3.58E+04	2.60E+04
2.07	1.13E-01	4.60E+01	2.86E+04	2.02E+04	2.63	1.29E-01	4.31E+01	2.14E+04	1.58E+04	2.30	2.91E-01	2.15E+00	1.97E+04	1.29E+04
4.25	1.27E-01	4.44E+01	2.67E+04	1.77E+04	4.63	5.86E-02	2.15E+00	2.05E+04	1.24E+04	4.27	2.21E-01	2.15E+00	2.02E+04	1.03E+04
8.18	3.16E-02	7.63E+01	2.77E+04	1.63E+04	8.63	9.21E-02	2.15E+00	2.02E+04	1.04E+04	7.35	1.17E-01	2.62E+00	1.66E+04	8.13E+03
24.17	1.80E-01	2.56E+00	2.45E+04	1.30E+04	24.75	2.62E-01	2.15E+00	2.16E+04	8.32E+03	24.15	2.32E-01			
48.18	4.96E-02	1.01E+02	2.36E+04	1.34E+04	48.60	8.78E-02	2.15E+00	1.58E+04	5.13E+03	48.23	1.38E-01	2.77E+00	6.28E+03	6.00E+03
168.40	1.69E-01	3.42E+00	2.19E+04	6.19E+03	96.10	7.24E-02	2.15E+00	1.51E+04	5.22E+03	96.15	9.17E-02	3.42E+00	2.43E+03	6.59E+03
239.45	1.61E-01	4.05E+00	1.86E+04	4.95E+03	168.37	5.80E-02	2.15E+00	9.25E+03	3.88E+03	167.93	9.84E-02	4.05E+00	2.03E+03	5.82E+03
Averages of Duplicate Tests - Bottle #08 and #23														
Time	25 Sr	25 Pu	25 Np	25 U	45 Time	45 Sr	45 Pu	45 Np	45 U	65 Time	65 Sr	65 Pu	65 Np	65 U
0	1.06E+02	2.80E+02	3.50E+04	2.46E+04	0	9.02E+01	2.69E+02	3.48E+04	2.50E+04	0	1.00E+02	2.67E+02	3.58E+04	2.60E+04
2.035	1.84E-01	5.37E+01	2.88E+04	2.04E+04	2.5	1.15E-01	4.24E+01	2.17E+04	1.58E+04	2.26	1.64E-01	2.15E+00	2.06E+04	1.31E+04
4.225	9.86E-02	4.99E+01	2.83E+04	1.87E+04	4.5	7.44E-02	2.15E+00	2.03E+04	1.23E+04	4.225	1.87E-01	2.15E+00	2.02E+04	1.03E+04
8.15	4.30E-02	3.95E+01	2.77E+04	1.65E+04	8.5	1.05E-01	2.15E+00	2.07E+04	1.07E+04	7.8	1.10E-01	2.38E+00	1.66E+04	8.16E+03
24.145	1.80E-01	2.56E+00	2.36E+04	1.26E+04	24.625	2.51E-01	2.15E+00	2.16E+04	8.20E+03	24.11	1.71E-01	2.15E+00	1.09E+04	5.82E+03
48.165	5.64E-02	6.77E+01	2.30E+04	1.13E+04	48.485	1.42E-01	2.15E+00	1.66E+04	5.39E+03	48.35	1.53E-01	2.46E+00	6.03E+03	5.98E+03
168.375	1.51E-01	3.42E+00	2.15E+04	6.19E+03	95.975	6.46E-02	2.15E+00	1.42E+04	4.88E+03	96.1	8.75E-02	2.78E+00	2.36E+03	6.54E+03
239.435	2.10E-01	4.05E+00	1.82E+04	4.86E+03	168.26	6.46E-02	2.15E+00	9.37E+03	3.82E+03	167.9	7.31E-02	3.10E+00	1.98E+03	5.80E+03

Appendix 24.

Mole Ratios of Sorbates to MST

Temp (C)	25	25	25	45	45	45	65	65	65
[Na+]	4.5M	6.0M	7.5M	4.5M	6.0M	7.5M	4.5M	6.0M	7.5M
High Activity [MST] = 0.2 g/L									
Mole ratios of Sr, Np, Pu and U to MST									
Units	mole ratio		mole ratio	mole ratio		mole ratio	mole ratio		mole ratio
Sr	7.23E-04		1.20E-03	6.16E-04		1.03E-03	6.86E-04		1.14E-03
Pu	7.03E-04		1.17E-03	6.74E-04		1.13E-03	6.69E-04		1.12E-03
Np	8.86E-02		1.48E-01	8.86E-02		1.47E-01	9.11E-02		1.51E-01
U	6.22E-02		1.03E-01	6.30E-02		1.05E-01	6.55E-02		1.09E-01
Total	1.52E-01		2.53E-01	1.53E-01		2.54E-01	1.58E-01		2.63E-01
Low Activity [MST] = 0.2 g/L									
Mole ratios of Sr, Np, Pu and U to MST									
Units	mole ratio		mole ratio	mole ratio		mole ratio	mole ratio		mole ratio
Sr	5.64E-05		9.41E-05	5.66E-05		9.41E-05	5.66E-05		9.41E-05
Pu	4.69E-06		4.11E-05	7.28E-06		1.21E-05	2.34E-06		6.03E-06
Np	1.43E-03		7.17E-03	2.48E-03		4.13E-03	1.49E-03		2.49E-03
U	6.39E-03		1.08E-02	6.55E-03		1.09E-02	5.80E-03		9.66E-03
Total	7.88E-03		1.81E-02	9.10E-03		1.52E-02	7.35E-03		1.23E-02
High Activity [MST] = 1.1 g/L									
Mole ratios of Sr, Np, Pu and U to MST									
Units	mole ratio								mole ratio
Sr	1.75E-04								1.66E-04
Pu	1.70E-04								1.62E-04
Np	2.15E-02								2.19E-02
U	1.50E-02								1.59E-02
Total	3.69E-02								3.82E-02
Low Activity [MST] = 1.1 g/L									
Mole ratios of Sr, Np, Pu and U to MST									
Units	mole ratio								mole ratio
Sr	1.37E-05								1.37E-05
Pu	5.07E-06								5.71E-07
Np	8.29E-04								3.62E-04
U	1.56E-03								1.41E-03
Total	2.41E-03								1.78E-03
High Activity [MST] = 2.0 g/L									
Mole ratios of Sr, Np, Pu and U to MST									
Units	mole ratio		mole ratio	mole ratio		mole ratio	mole ratio		mole ratio
Sr	7.23E-05		1.20E-04	6.16E-05		1.03E-04	6.86E-05		1.14E-04
Pu	7.03E-05		1.17E-04	6.74E-05		1.13E-04	6.69E-05		1.12E-04
Np	8.86E-03		1.48E-02	8.86E-03		1.47E-02	9.11E-03		1.51E-02
U	6.22E-03		1.03E-02	6.30E-03		1.05E-02	6.55E-03		1.09E-02
Total	1.52E-02		2.53E-02	1.53E-02		2.54E-02	1.58E-02		2.63E-02
Low Activity [MST] = 2.0 g/L									
Mole ratios of Sr, Np, Pu and U to MST									
Units	mole ratio		mole ratio	mole ratio		mole ratio	mole ratio		mole ratio
Sr	5.64E-06		9.41E-06	5.66E-06		9.41E-06	5.66E-06		9.41E-06
Pu	4.69E-07		4.11E-06	7.28E-07		1.21E-06	2.34E-07		6.03E-07
Np	1.43E-04		7.17E-04	2.48E-04		4.13E-04	1.49E-04		2.49E-04
U	6.39E-04		1.08E-03	6.55E-04		1.09E-03	5.80E-04		9.66E-04
Total	7.88E-04		1.81E-03	9.10E-04		1.52E-03	7.35E-04		1.23E-03

Appendix 25.
Statistical Analysis of Mixing Trials

[Np] e (microg/L) By Temp (Deg C) **[U] e (microg/L) By Temp (Deg C)** **[Np] e (microg/L) By Mixing** **[U] e (microg/L) By Mixing** **[U] e (microg/L) By Activity** **[Pu] e (microg/L) By Activity**

[Pu] e (microg/L) By Temp (Deg C) **[Pu] e (microg/L) By Mixing**

Response: [Sr] e (microg/L)
Summary of Fit

RSquare	0.78336
RSquare Adj	0.723182
Root Mean Square Error	0.013283
Mean of Response	0.066838
Observations (or Sum Wgts)	24

Source	DF	Sum of Squares	Mean Square	Lack of Fit F Ratio
Lack of Fit	6	0.00227044	0.000378	5.0162
Pure Error	12	0.00090523	0.000075	Prob>F
Total Error	18	0.00317568		0.0086
Max RSq				
0.9382				

Parameter Estimates				
Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	0.0162352	0.0142	1.14	0.2679
Temp (Deg C)	0.001638	0.000256	6.39	<.0001
[Sr]o (microg/L	-0.00206	0.001088	-1.89	0.0746
[Sr]o (m*Temp (De	-0.000019	0.000005	-4.15	0.0006
[Sr]o (m*[Sr]o (m	0.0000322	0.000012	2.79	0.0120
Mixing[No-Yes]	0.0084708	0.002711	3.12	0.0059

Whole-Model Test

Residual Plot

Analysis of Variance				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	0.01148310	0.002297	13.0174
Error	18	0.00317568	0.000176	Prob>F
C Total	23	0.01465878		<.0001

Response: [Np] e (microg/L)**Summary of Fit**

RSquare	0.994623
RSquare Adj	0.993129
Root Mean Square Error	574.3948
Mean of Response	5083.521
Observations (or Sum Wgts)	24

Source	DF	Sum of Squares	Mean Square	Lack of Fit F Ratio
Lack of Fit	6	1189166.4	198194	0.5007
Pure Error	12	4749562.2	395797	Prob>F
Total Error	18	5938728.6		0.7964

Max RSq

0.9957

Term	Estimate	Std Error	t Ratio	Parameter Estimates Prob> t
Intercept	-4910.447	1156.018	-4.25	0.0005
Temp (Deg C)	55.701983	14.90214	3.74	0.0015
[Np]o (microg/L	3.754129	0.74355	5.05	<.0001
[Np]o (m*Temp (De	-0.014407	0.000522	-27.60	<.0001
[Np]o (m*[Np]o (m	-0.000094	0.000026	-3.67	0.0017
Mixing[No-Yes]	148.12917	117.2478	1.26	0.2226

Whole-Model Test **Residual Plot** **Analysis of Variance**

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	1098449960	2.1969e8	665.8698
Error	18	5938728.62	329929.4	Prob>F
C Total	23	1104388688		<.0001

Response: [Pu] e (microg/L)

Summary of Fit

RSquare	0.987439
RSquare Adj	0.984795
Root Mean Square Error	0.049667
Mean of Response	0.694417
Observations (or Sum Wgts)	24

Lack of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack of Fit	7	0.03718282	0.005312	6.5802
Pure Error	12	0.00968700	0.000807	Prob>F
Total Error	19	0.04686982		0.0024
Max RSq				
0.9974				

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	0.6345469	0.043038	14.74	<.0001
Temp (Deg C)	-0.007309	0.000893	-8.18	<.0001
[Pu]o (microg/L	0.0018694	0.000276	6.77	<.0001
[Pu]o (m*Temp (De	0.0000376	0.000006	6.49	<.0001
Mixing[No-Yes]	0.0278333	0.010138	2.75	0.0129

Whole-Model Test

Residual Plot

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	4	3.6845200	0.921130	373.4059
Error	19	0.0468698	0.002467	Prob>F
C Total	23	3.7313898		<.0001

Response: [U] e (microg/L)
Summary of Fit

RSquare	0.99439
RSquare Adj	0.99241
Root Mean Square Error	333.4778
Mean of Response	3816.237
Observations (or Sum Wgts)	24

Source	DF	Sum of Squares	Mean Square	Lack of Fit F Ratio
Lack of Fit	5	408710.3	81742	0.6620
Pure Error	12	1481816.8	123485	Prob>F
Total Error	17	1890527.1		0.6592
Max RSq				
0.9956				

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	9962.9249	3904.042	2.55	0.0206
Temp (Deg C)	178.16786	115.4564	1.54	0.1412
[U]o (microg/L)	-6.851213	3.076783	-2.23	0.0398
Temp (De*Temp (De	-2.098337	1.353951	-1.55	0.1396
Temp (De*[U]o (mi	-0.009513	0.003325	-2.86	0.0108
[U]o (mi*[U]o (mi	0.0003471	0.000146	2.38	0.0290
Mixing[No-Yes]	111.20417	68.07088	1.63	0.1207

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	6	335118955	55853159	502.2428
Error	17	1890527	111207.5	Prob>F
C Total	23	337009482		<.0001

Response: $\ln\{[U] e \text{ (microg/L)}\}$

Summary of Fit

RSquare	0.998586
RSquare Adj	0.998194
Root Mean Square Error	0.094828
Mean of Response	6.74258
Observations (or Sum Wgts)	24

Source	DF	Sum of Squares	Mean Square	Lack of Fit F Ratio
Lack of Fit	6	0.03552834	0.005921	0.5624
Pure Error	12	0.12633490	0.010528	Prob>F
Total Error	18	0.16186324		0.7525
Max RSq				
0.9989				

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	4.0706905	0.20078	20.27	<.0001
Temp (Deg C)	-0.009749	0.009406	-1.04	0.3137
[U]o (microg/L)	0.0002774	0.000006	43.85	<.0001
Temp (De*Temp (De	0.0001967	0.000103	1.92	0.0714
Temp (De*[U]o (mi	-8.229e-7	1.296e-7	-6.35	<.0001
Mixing[No-Yes]	0.0162623	0.019357	0.84	0.4119

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	114.34403	22.8688	2543.125
Error	18	0.16186	0.0090	Prob>F
C Total	23	114.50589		<.0001

Appendix 26.
Statistical Analysis of NaTPB and Sludge Addition (Spiked) Trials

[Np] e (microg/L) By Temp (Deg C) **[U] e (microg/L) By Temp (Deg C)** **[Np] e (microg/L) By Spiked** **[U] e (microg/L) By Spiked** **[U] e (microg/L) By Activity** **[Pu] e (microg/L) By Activity**

Response: [Sr] e (microg/L)
Summary of Fit

RSquare	0.82359
RSquare Adj	0.761328
Root Mean Square Error	0.020963
Mean of Response	0.07675
Observations (or Sum Wgts)	24

Source	DF	Sum of Squares	Mean Square	Lack of Fit F Ratio
Lack of Fit	11	0.00677429	0.000616	5.3055
Pure Error	6	0.00069646	0.000116	Prob>F
Total Error	17	0.00747075		0.0262
Max RSq				
0.9836				

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	0.075559	0.044936	1.68	0.1110
Temp (Deg C)	-0.003034	0.002092	-1.45	0.1651
[Sr]o (microg/L	0.0012373	0.000327	3.79	0.0015
Temp (De*Temp (De	0.0000648	0.000023	2.85	0.0111
Temp (De*[Sr]o (m	-0.000003	0.000007	-4.38	0.0004
Spiked[SS-zNo]	0.0197056	0.00669	2.95	0.0090
Spiked[TPB-zNo]	0.0048056	0.00669	0.72	0.4823

Source	DF	Sum of Squares	Mean Square	Analysis of Variance F Ratio
Model	6	0.03487805	0.005813	13.2277
Error	17	0.00747075	0.000439	Prob>F
C Total	23	0.04234880		<.0001

Response: [Np] e (microg/L)
Summary of Fit

RSquare	0.979607
RSquare Adj	0.972409
Root Mean Square Error	1052.326
Mean of Response	4826.508
Observations (or Sum Wgts)	24

Source	DF	Sum of Squares	Mean Square	Lack of Fit F Ratio
Lack of Fit	11	15137523	1376138	2.2388
Pure Error	6	3688104	614684	Prob>F
Total Error	17	18825628		0.1670
Max RSq				
0.9960				

Parameter Estimates				
Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	-4983.857	2119.106	-2.35	0.0310
Temp (Deg C)	55.318278	27.30162	2.03	0.0587
[Np]o (microg/L	3.7396569	1.362228	2.75	0.0138
Temp (De*[Np]o (m	-0.012261	0.000956	-12.82	<.0001
[Np]o (m*[Np]o (m	-0.000098	0.000047	-2.08	0.0530
Spiked[SS-zNo]	47.269444	335.8418	0.14	0.8897
Spiked[TPB-zNo]	-192.4472	335.8418	-0.57	0.5741

Analysis of Variance				
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	6	904307220	1.5072e8	136.1019
Error	17	18825628	1107390	Prob>F
C Total	23	923132847		<.0001

Response: [Pu] e (microg/L)
Summary of Fit

RSquare	0.984464
RSquare Adj	0.980148
Root Mean Square Error	0.064295
Mean of Response	0.635908
Observations (or Sum Wgts)	24

Source	DF	Sum of Squares	Mean Square	Lack of Fit F Ratio
Lack of Fit	12	0.07045123	0.005871	8.8987
Pure Error	6	0.00395850	0.000660	Prob>F
Total Error	18	0.07440973		0.0069
Max RSq				
0.9992				

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	0.2229717	0.041386	5.39	<.0001
Temp (Deg C)	-0.001661	0.000826	-2.01	0.0597
[Pu]o (microg/L	0.0143264	0.003674	3.90	0.0011
[Pu]o (m*[Pu]o (m	-0.000047	0.000017	-2.78	0.0122
Spiked[SS-zNo]	-0.052717	0.020519	-2.57	0.0193
Spiked[TPB-zNo]	0.0118167	0.020519	0.58	0.5718

Source	DF	Sum of Squares	Mean Square	Analysis of Variance F Ratio
Model	5	4.7151045	0.943021	228.1204
Error	18	0.0744097	0.004134	Prob>F
C Total	23	4.7895143		<.0001

Response: [U] e (microg/L)
Summary of Fit

RSquare	0.988853
RSquare Adj	0.984919
Root Mean Square Error	478.9525
Mean of Response	3874.471
Observations (or Sum Wgts)	24

Source	DF	Sum of Squares	Mean Square	Lack of Fit F Ratio
Lack of Fit	11	2910301.1	264573	1.6044
Pure Error	6	989422.4	164904	Prob>F
Total Error	17	3899723.5		0.2909

Max RSq
0.9972

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	2710.9398	2388.599	1.13	0.2721
Temp (Deg C)	0.8356381	9.738126	0.09	0.9326
[U]o (microg/L)	-1.338496	1.178368	-1.14	0.2718
Temp (De*[U]o (mi	-0.00313	0.001429	-2.19	0.0427
[U]o (mi*[U]o (mi	0.0000856	0.000056	1.53	0.1432
Spiked[SS-zNo]	489.93333	152.854	3.21	0.0052
Spiked[TPB-zNo]	-264.0167	152.854	-1.73	0.1022

Whole-Model Test

Residual Plot

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	6	345954779	57659130	251.3525
Error	17	3899723	229395.5	Prob>F
C Total	23	349854503		<.0001

Appendix 27.
Statistical Analysis of Standard Trials

[Sr] e (microg/L) By Activity

[Sr] e (microg/L) By MST (g/L)

[Sr] e (microg/L) By Temp (Deg C)

[Sr] e (microg/L) By Z (M)

[Np] e (microg/L) By Activity **[Np] e (microg/L) By Z (M)** **[Np] e (microg/L) By Temp (Deg C)** **[U] e (microg/L) By Activity** **[Np] e (microg/L) By MST (g/L)** **[U] e (microg/L) By Temp (Deg C)**

[U] e (microg/L) By MST (g/L) **[Pu] e (microg/L) By Temp (Deg C)** **[U] e (microg/L) By Z (M)** **[Pu] e (microg/L) By MST (g/L)** **[Pu] e (microg/L) By Activity** **[Pu] e (microg/L) By Z (M)**

Response: [Sr] e (microg/L)**Summary of Fit**

RSquare	0.972511
RSquare Adj	0.966212
Root Mean Square Error	0.108897
Mean of Response	0.403816
Observations (or Sum Wgts)	60

Lack of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack of Fit	18	0.49333146	0.027407	10.8358
Pure Error	30	0.07587984	0.002529	Prob>F
Total Error	48	0.56921129		<.0001
Max RSq				
0.9963				

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	4.4260523	0.545442	8.11	<.0001
Temp (Deg C)	0.0057391	0.001746	3.29	0.0019
MST (g/L)	1.0220629	0.086406	11.83	<.0001
Z (M)	-1.678261	0.171502	-9.79	<.0001
[Sr]o (microg/L	-0.003138	0.002353	-1.33	0.1887
MST (g/L*Temp (De	-0.004937	0.00107	-4.62	<.0001
Z (M)*MST (g/L	-0.181079	0.011037	-16.41	<.0001
Z (M)*Z (M)	0.158784	0.013139	12.09	<.0001
[Sr]o (m*Temp (De	0.0000832	0.000023	3.64	0.0007
[Sr]o (m*MST (g/L	-0.001643	0.000466	-3.53	0.0009
[Sr]o (m*Z (M)	-0.001194	0.000744	-1.61	0.1148
[Sr]o (m*[Sr]o (m	0.000116	0.000052	2.21	0.0318

Whole-Model Test **Residual Plot** **Analysis of Variance**

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	11	20.137852	1.83071	154.3790
Error	48	0.569211	0.01186	Prob>F
C Total	59	20.707063		<.0001

Response: [Np] e (microg/L)**Summary of Fit**

RSquare	0.978018
RSquare Adj	0.974061
Root Mean Square Error	1078.153
Mean of Response	5138.887
Observations (or Sum Wgts)	60

Lack of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack of Fit	20	50060484	2503024	9.3162
Pure Error	30	8060220	268674	Prob>F
Total Error	50	58120704		<.0001
Max RSq				
0.9970				

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	2141.8395	2087.026	1.03	0.3097
Temp (Deg C)	-12.58601	40.6197	-0.31	0.7580
MST (g/L)	-240.1614	855.3771	-0.28	0.7800
Z (M)	-652.3456	309.3746	-2.11	0.0400
[Np]o (microg/L	0.9672846	0.032253	29.99	<.0001
MST (g/L*Temp (De	-31.10862	10.58849	-2.94	0.0050
Z (M)*Temp (De	8.5525546	5.952871	1.44	0.1570
Z (M)*MST (g/L	238.24447	108.5936	2.19	0.0329
[Np]o (m*Temp (De	-0.010349	0.000604	-17.13	<.0001
[Np]o (m*MST (g/L	-0.116386	0.012242	-9.51	<.0001

Whole-Model Test **Residual Plot** **Analysis of Variance**

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	9	2585854584	2.8732e8	247.1728
Error	50	58120703.6	1162414	Prob>F
C Total	59	2643975288		<.0001

Response: [Pu] e (microg/L)**Summary of Fit**

RSquare	0.789178
RSquare Adj	0.735351
Root Mean Square Error	0.754799
Mean of Response	1.190233
Observations (or Sum Wgts)	60

Lack of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack of Fit	18	26.638479	1.47992	310.0665
Pure Error	29	0.138414	0.00477	Prob>F
Total Error	47	26.776893		<.0001
Max RSq				
0.9989				

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	7.4014219	4.06853	1.82	0.0753
Temp (Deg C)	-0.053605	0.055159	-0.97	0.3361
MST (g/L)	0.2756018	0.598912	0.46	0.6475
Z (M)	-2.130129	1.201773	-1.77	0.0828
[Pu]o (microg/L	0.0187144	0.004975	3.76	0.0005
Temp (De*Temp (De	0.0013112	0.000522	2.51	0.0155
MST (g/L*Temp (De	0.0195974	0.007416	2.64	0.0111
Z (M)*Temp (De	-0.019199	0.004057	-4.73	<.0001
Z (M)*MST (g/L	-0.302035	0.075931	-3.98	0.0002
Z (M)*Z (M)	0.2943405	0.090731	3.24	0.0022
[Pu]o (m*MST (g/L	0.0041287	0.001095	3.77	0.0005
[Pu]o (m*Z (M)	0.0122774	0.003746	3.28	0.0020
[Pu]o (m*[Pu]o (m	-0.00046	0.000108	-4.27	<.0001

Whole-Model Test **Residual Plot** **Analysis of Variance**

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	12	100.23506	8.35292	14.6614
Error	47	26.77689	0.56972	Prob>F
C Total	59	127.01195		<.0001

Response: [U] e (microg/L)**Summary of Fit**

RSquare	0.97865
RSquare Adj	0.975776
Root Mean Square Error	834.2169
Mean of Response	4365.92
Observations (or Sum Wgts)	60

Source	DF	Lack of Fit Sum of Squares	Mean Square	F Ratio
Lack of Fit	22	31509027	1432228	9.1835
Pure Error	30	4678700	155957	Prob>F
Total Error	52	36187726		<.0001
Max RSq				
0.9972				

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	15483.209	4134.61	3.74	0.0005
MST (g/L)	-2484.638	549.6486	-4.52	<.0001
Z (M)	-4647.965	1314.154	-3.54	0.0009
[U]o (microg/L)	0.8238358	0.064824	12.71	<.0001
Z (M)*MST (g/L)	349.48268	84.79758	4.12	0.0001
Z (M)*Z (M)	328.50277	100.5494	3.27	0.0019
[U]o (mi*MST (g/L	-0.274538	0.014271	-19.24	<.0001
[U]o (mi*Z (M)	-0.013684	0.008611	-1.59	0.1181

Whole-Model Test **Residual Plot** **Analysis of Variance**

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	7	1658818781	2.3697e8	340.5203
Error	52	36187726.2	695917.8	Prob>F
C Total	59	1695006507		<.0001

Prediction Limits and Measurements Versus Model Predictions for [Sr] e (microg/L)

Prediction Limits and Measurements Versus Model Predictions for [Np] e (microg/L)

Prediction Limits and Measurements Versus Model Predictions for [Pu] e (microg/L) **Prediction Limits and Measurements Versus Model Predictions for [U] e (microg/L)**

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