WSRC-TR-2006-00246

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Distribution Coefficients,
Cobalt, Cesium
Strontium

RETENTION:
Permanent

DISTRIBUTION COEFFICIENTS FOR THE VOGTLE EARLY SITE PERMIT

Daniel I. Kaplan and Margaret R. Millings

JULY 18, 2006

Savannah River National Laboratory
Washington Savannah River Company
Savannah River Site
Aiken, SC 29808

Prepared for the U.S. Department of Energy Under
Contract Number DE-AC09-96SR18500

SRNL

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REVIEWS AND APPROVALS

Daniel I. Kaplan, Co-author, Waste Processing Technology — Date 7/25/2006

Margaret Millings, Co-author, Environmental Science and Biotechnology — Date 7/25/06

Kim Crapse, Peer Reviewer, Waste Processing Technology — Date 7/25/2006

B. Thomas Butcher, Level 4 Manager, Waste Processing Technology — Date 7/25/2006

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CEC	Cation exchange capacity
ESP	Early Site Permit
Kd	Distribution Coefficient
SNC	Southern Nuclear Company
SRNL	Savannah River National Laboratory

ABSTRACT

A series of sediment distribution coefficients, Kd values, measurements were conducted for Southern Nuclear Company, Inc. in support of their Early Site Permit application at Plant Vogtle, Georgia. Nineteen sediment and a representative groundwater samples from the Vogtle site were provided for the Savannah River National Laboratory to conducted site-specific Co, Cs, and Sr Kd measurements. The median Kd values of Co was 6.5 mL/g, for Sr was 10.0 mL/g, and for Cs was 18.8 mL/g. Cation exchange capacity (6.8 to 33.6 meq/100 g), particle size distribution (70 to 94% sand) and pH (4.7 to 5.2) were also measured in five sediments. The Kd values and the sediment properties values measured in these sediments were consistent with those measured in this region of the country.

1.0 INTRODUCTION

Distribution coefficients, Kd values, when used in reactive transport codes are conditional on the sediment type and groundwater (Krupka et al 1999). For this reason it is ideal to use Kd values derived from site-specific materials when possible. The objective of this project was to provide site-specific cobalt (Co), cesium (Cs), and strontium (Sr) Kd values for the Plant Vogtle Early Site Permit. To approach was to collect sediment samples along a hypothetical plume path and to use these samples along with site specific groundwater to conduct Kd tests.

2.0 MATERIALS AND METHODS

2.1 MATERIALS

The Materials and Methods are described in detail in Appendix A. The following is a brief description to permit understanding of the results. Nineteen sediment and groundwater samples collected from the Plant Vogtle site in Georgia were provided by MACTEC. The radionuclides used in the Kd measurements were from a solution containing several gamma emitters. This solution is typically used as a standard for calibrating instruments and was purchased from Analytics, Inc. (Atlanta, GA; 3 µCi source of Radionuclide Mixture Option 4; http://www.analyticsinc.com/prod01.htm). This spike solution is described in more detail in Appendix B. The solution contained 10 isotopes; the three of interested were as follows.

- ^{60}Co: The purchased spike solution contained 1.6e-9 Ci/L and the sediments suspension was initially spiked at a concentration of 1.1e-12 Ci/L.
- ^{137}Cs: The purchased spike solution contained 9.8e-10 Ci/L and the sediments suspension was initially spiked at a concentration of 6.5e-13 Ci/L.
- ^{85}Sr: The purchased spike solution contained 2.7e-9 Ci/L and the sediments suspension was initially spiked at a concentration of 1.8e-12 Ci/L.

The magnitude of sorption does not vary with isotope. So even if the Early Site Permit is interested in making transport calculations with different isotopes of Co, Cs, and Sr than those used in those tests, the Kd values will remain the same. At these very low concentrations, competition for sorption sites as a result of introducing more than one radionuclide at a time will be essentially non-existent.

The source solution was carefully selected so that the concentrations of Co, Cs, and Sr would not exceed the linear sorption range. In the linear range, Kd values are appropriate to use, at higher concentrations, it is often necessary to use more complicated models, such as the Freundlich model, and yet at higher concentrations, precipitation of the radionuclide of interest may occur. If precipitation occurs, the measurement would incorrectly attribute reversible sorption to the Kd values, where in fact “irreversible” precipitation occurred. (The latter should be described using a solubility constant and not a Kd value.) The tests were conducted at several orders of magnitude lower concentrations than would be necessary for precipitation of Co, Cs, or Sr. Regarding non-linear sorption, Krupka et al. (1999) reported

that non-linear sorption of Cs occurs at concentration greater than about 10^{-5} M (0.12 Ci/L ^{137}Cs) and Sr at about 10^{-7} M (1.2e-3 Ci/L ^{90}Sr). Clearly, the concentrations used in these Kd tests are several orders of magnitude lower than where non-linear sorption occurs. As will be shown below, a sediment may contain 10 meq exchange sites per 100 g sediment and a test system contained 1e-7 meq of radionuclides 100 g sediment. Thus, the number of exchange sites did not limit radionuclide sorption.

2.2 METHODS

2.2.1 Distribution Coefficients

A detailed description of the methods used in measuring Kd values is presented in Appendix A. Briefly, each sample was thoroughly mixed and than approximately 100 g sub-samples were dried at 85 °C in a drying oven. 1-g of dried sediment was added to a centrifuge tube, followed by 12 mL of groundwater. The suspension was mixed overnight to pre-equilibrate the sediments with the groundwater chemistry prior to adding the radionuclide spike. To separate the phases, the tubes were centrifuged and the aqueous phase was decanted and disposed.

Following pre-equilibrating the sediment sample, 10 mL groundwater was added to the tubes followed by 80 µL of a gamma standard spike, and 74 µL 4 M NaOH. The NaOH solution was added because the background solution of the spike was 4 M HCl and this strong acid would change the pH of the sediment suspension. It is important to maintain sediment pH because pH can greatly influence the extent that radionuclides sorb to sediments. Preliminary test showed that 74 µL 4 M NaOH was sufficient to bring the pH of sandy sediment soils and clayey sediment soils back to their original pH once they received 80-µL of 4 M HCl. pH was measured in selected tubes to confirm that it was within pH 5 to 6.5. The suspensions were periodically shaken over a 7 day contact period. At the end of the contact period, the samples were permitted to settle and the aqueous phase was passed through a 0.45µm filter and analyzed by standard gamma spectroscopy. All Kd measurements were conducted in duplicate. Three positive controls were included (spikes only in groundwater) and three blank controls were included (DI water; laboratory controls provided by Analytical Development Services, SRNL, <u>not</u> groundwater/sediment controls). Therefore a total of:

> (2 reps x 19 sediments) + 3 positive controls + 3 negative controls = 44 test tube measurements were made.

The three positive controls were used to provide estimates of radionuclide concentrations in the absence of sediment and accounted for any sorption to the labware that may have occurred as an experimental artifact. It also provided a measure of analytical error; concentrations in the control were 310±11 dpm/mL ^{60}Co, 195±15 dpm/mL ^{85}Sr, and 197±14 dpm/mL ^{137}Cs. All blanks (negative controls) were below detection limit.

2.2.2 Sediment and Groundwater Characterization

Five sediments were characterized for cation exchange capacity (CEC) pH, and particle size distribution (sand-silt-clay). The five sediments selected for characterization varied in color, an indication of varying mineralogy and/or organic matter content, and particle size distribution. The CEC was determined using EPA Method 9080/9801, which uses 1 N ammonium acetate as the exchange solution. Particle size distribution was determined by standard hydrometer (silt and clay) and sieve (sand) methods (ASTM D-422, ASTM D-1140). pH was determined in a 1:1 water: sediment suspension that had been permitted to equilibrate for an hour prior to measurement. MACTEC conducted the CEC and particle size distribution tests.

Groundwater was analyzed following standard procedures for pH, total dissolved solids, major cations by ICP-AES, major anions by IC. The results from the groundwater characterization are presented in Appendix E.

3.0 DISCUSSION

The Kd values for the 19 sediments are presented in Table 1 and associated descriptive statistics are presented in Table 2. A general ranking of the radionuclides in order of their Kd values is: Co < Sr < Cs. Since there were "greater than" values with the Cs Kd values, the median may be a useful statistic to use to compare the radionuclides. Again, the ranking would be Co < Sr < Cs, which had median Kd values of 6.5, 10.0, and 18.8 mL/g. This ranking of the radionuclides is consistent with general geochemical principles and are consistent with the ranking reported in Thibault et al. 1990. Furthermore, the Kd values are consistent with those measured at the Savannah River Site (SRS). On the SRS, Sr Kd values for sandy sediments are generally around 5 mL/g and for clayey sediment closer to 17 mL/g (Kaplan 2006). Co Kd values in sandy and clayey SRS sediments are 7 and 30 mL/g, respectively (Kaplan 2006). Cs Kd values in sandy and clayey SRS sediments are 15 and 180 mL/g, respectively (Kaplan 2006).

Table 1. Co, Cs, and Sr Kd Values (Average of Two Values).

Soil	Co Kd (mL/g)	Sr Kd (mL/g)	Cs Kd (mL/g)
A-10(a)	8.1	13.2	56.2
C-7	3.9	9.0	14.8
D-10	1.7	7.8	9.9
E-7	10.1	25.7	19.9
E-12	15.3	51.7	10.7
G-9	7.9	9.8	> 25.5
J-11	13.5	9.2	> 47.4
K-10	15.2	10.0	19.3
L-7	1.7	11.4	18.8
M-5	7.3	9.3	16.8
N-3	5.8	10.7	7.8
P-8	6.5	7.0	5.3
Q-7	3.2	9.3	14.6
H-6	1.4	6.0	3.5
S-9	3.0	8.6	19.3
R-8	2.1	10.5	13.5
B-1003V-55-65	10.9	17.4	> 30.1
B-1003V-65-75	3.9	15.0	22.7
B-1003V-75-82	21.3	14.4	33.2

(a) A-10 = Test Pit A, 10 feet deep, Sample depth 10 ft.

Table 2. Descriptive Statistics of the Kd Values (mL/g).

Column1	*Co Kd*	Sr Kd	Cs Kd*
Mean	7.5	13.5	NA
Standard Error	1.3	2.4	NA
Median	6.5	10.0	18.8
Mode	NA	NA	NA
Standard Deviation	5.62	10.29	NA
Sample Variance	31.59	105.95	NA
Range	19.94	45.75	>52
Minimum	1.36	5.98	3.45
Maximum	21.30	51.74	>56.2

* Cs Kd include greater than values therefore complete statistics were not possible to conduct.

Regarding the three greater than Cs Kd values, it would be ideal to repeat these measurements with larger water to sediment ratios, or better yet, to simply measure the Cs remaining on the sediments. (Kd measurements are based on the amount of radionuclide in the aqueous phase before and after contact with the sediment.) Given the schedule and budget of the project, this option was not available.

3.1 SEDIMENT CEC, SAND-SILT-CLAY CONTENT, AND pH

Sediment CEC, particle size distribution and pH were measured on five sediments. The results are presented in Figure 1 and summarized in Table 3. As the photos in Figure 1 demonstrate, the sediments varied greatly in color and particle size distribution (70% to 94% sand). The pH varied very little, from 4.7 to 5.24. Such acidic subsurface sediments are typical of this region. The CEC values ranged from 6.8 to 24.0 meq/100 g. Not surprisingly, there was no significant correlation between these parameters and Kd values at the probability level of 0.05 due to the limited number of samples collected (correlation matrix is provided in Appendix D).

Figure 1. Sediment Selected for Characterization

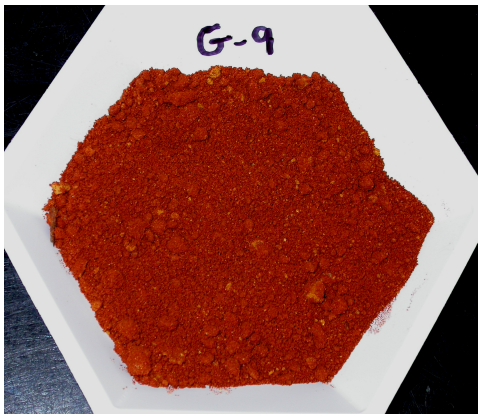
Figure 1. Sediment Selected for Characterization (Continuation)

Sample E-12

Avg Co Kd	15.3
Avg Sr Kd	51.7
Avg Cs Kd	10.7
CEC (meq/100g)	18.9
% Sand	80.2
% Silt	19.6
% Clay	0.2
Soil pH	4.95

Sample G-9

Avg Co Kd	7.9
Avg Sr Kd	9.8
Avg Cs Kd	>25.5
CEC (meq/100g)	33.6
% Sand	69.8
% Silt	21.5
% Clay	8.7
Soil pH	4.97



Sample N-3

Avg Co Kd	5.8
Avg Sr Kd	10.7
Avg Cs Kd	7.8
CEC (meq/100g)	24
% Sand	87
% Silt	9.9
% Clay	3.1
Soil pH	4.7

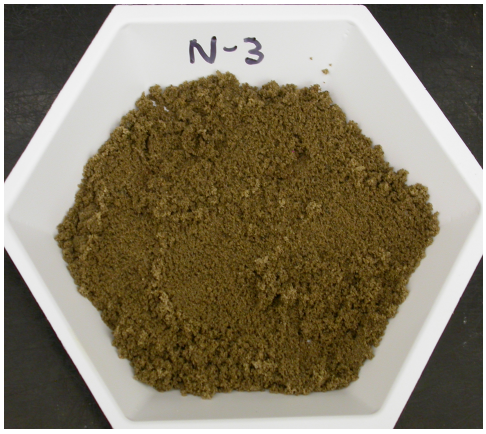
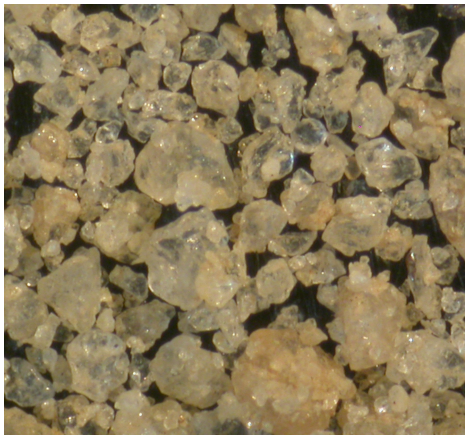


Figure 1. Sediment Selected for Characterization (Continuation)

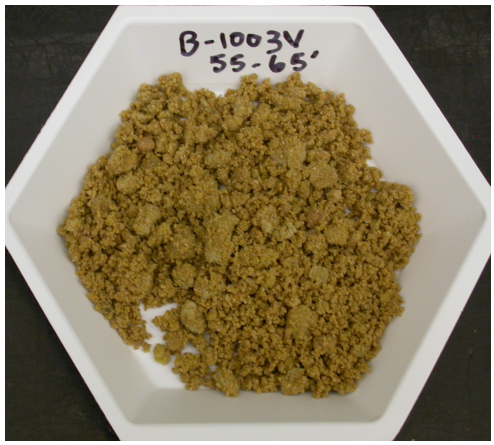
Sample P-8

Avg Co Kd	6.5
Avg Sr Kd	7.0
Avg Cs Kd	5.3
CEC (meq/100g)	6.8
% Sand	94.3
% Silt	3.7
% Clay	2
Soil pH	4.93



Sample B-1003V-55-65

Avg Co Kd	10.9
Avg Sr Kd	17.4
Avg Cs Kd	>30.1
CEC (meq/100g)	12.3
% Sand	87.7
% Silt	10.4
% Clay	1.9
Soil pH	5.24



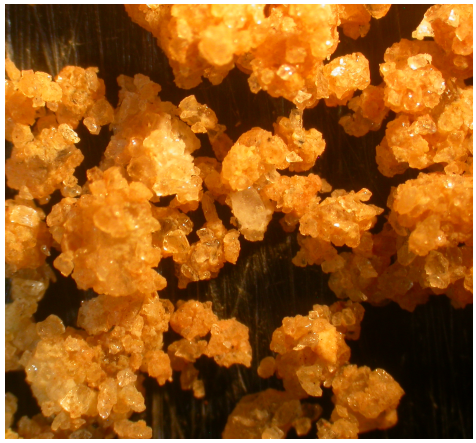


Table 3. Kd values, CEC, pH, and Particle Size Distribution of Five Sediments.

Soil Samples	Co Kd (mL/g)		Sr Kd (mL/g)		Cs Kd (mL/g)			CEC (meq/100 g)	%Sand	%Silt	%Clay	soil pH (DI water)
	Avg	Stdev	Avg	Stdev		Avg	Stdev					
E-12	15.3	0.0	51.7	0.0		10.7	0.0	18.9	80.2	19.6	0.2	4.95
G-9	7.9	0.9	9.8	1.4	>	25.5	3.9	33.6	69.8	21.5	8.7	4.97
N-3	5.8	3.0	10.7	2.1		7.8	6.2	24	87	9.9	3.1	4.7
P-8	6.5	8.0	7.0	2.5		5.3	1.7	6.8	94.3	3.7	2	4.93
B-1003V-55-65	10.9	3.3	17.4	3.1	>	30.1	0.6	12.3	87.7	10.4	1.9	5.24

CEC=Cation Exchange Capacity, EPA method 9080/9801; 4.75mm<Sand>0.074mm; 0.074mm<Silt>0.005mm; Clay<0.005mm; CEC and Grain Size analyses conducted by GeoTesting Express, Inc

4.0 REFERENCES

Kaplan, D. I. 2006. Geochemical Data Package for Performance Assessment Calculations Related to the Savannah River Site. WSRC-TR-2006-00004, Rev. 0. Washington Savannah River Company, Aiken, SC.

Krupka, K. M., D. I. Kaplan, G. Whelan, R. J. Serne, and S. V. Mattigod. 1999. Understanding Variation in Partition Coefficient, Kd, Values. Volume 1: The Kd Model, Methods of Measurement, and Application of Chemical Reaction Codes. EPA 402-R-99-004A. Office of Air and Radiation, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, DC. (http://www.epa.gov/radiation/cleanup/partition.htm)

Thibault, D. H., M. I. Sheppard, and P. A. Smith. 1990. A critical Compilation and Review of Default Soil Solid/Liquid Partition Coefficients, Kd, For Use in Environmental Assessments. AESC-10125. Whiteshell Nuclear Research Establishment, Pinawa, Manitoba, Canada.

APPENDIX A. Detailed Description of the Materials and Methods

Materials and Methods for K_d Measurements of Vogtle Site Sediments

Objective

Measure Co, Cs, and Sr Kd values of 19 sediments collected from Plant Vogtle in Georgia. Because these Kd values will be used in a reactive transport code as part of a Early Site Permit Project for Southern Nuclear Company, all attempts will be made to make the experimental conditions of the tests representative of an accidental release. These measurements will include site-specific sediments, site-specific groundwater, and radionuclides concentrations that are in the linear sorption range. The linear sorption range is the lower range in an adsorption isotherm (x-axis: aqueous solute concentration, y-axis: sorbed concentration) before non-linearity occurs (the result of limitations of sorption sites with respect to aqueous radionuclide concentrations).[1] Furthermore, the sediments were pre-equilibrated with the groundwater prior to spiking with radionuclides, again to minimize "shocking the chemistry" and to provide a measure of steady state conditions, as implied by the Kd construct.

Materials

1. 19 Vogtle ESP site sediments samples
2. Vogtle ESP site groundwater
3. 3 µCi source of Radionuclide Mixture Option 4 from Analytics, Inc. (http://www.analyticsinc.com/prod01.htm)
4. 15-mL centrifuge tubes
5. sandwich baggies
6. large weighing boats
7. 0.45-µm syringe filters
8. 4-M NaOH

Methods

1. Collecting representative subsample: Mix field-moist sediments in bags. Remove a total of ~100 g from several locations within a bag. Place in labeled aluminum weighing boats and place in oven at 85°C until no weight change is noted.
2. Record "Tube Tare (g)" weight (without cap) of labeled 15-mL centrifuge tube.
3. Add 1±0.01-g soil to each tube. Weigh and record "Soils (g)"
4. Add 12-mL groundwater to each tube. Put on shaker for overnight. Let sit for 1 hr. Let decant liquid. If necessary, centrifuge at 15 min 6000 rpm. Then decant liquid. Throw away liquid. Error on the side of leaving liquid in tube rather than

[1] From a risk assessment point of view, it is important not to promote precipitation of the radionuclide by introducing too high a spike concentration into the sediment-groundwater system. This may be construed by regulators and reviewers of the ESP as a **non-conservative** estimate of the sorption capacity of the sediment for the radionuclide. Additionally, this may result in the precipitation of radionuclide to glassware, an experimental artifact that would be difficult (costly) to identify.

accidentally loosing clays down the drain. Record weight of each tube in "Tube + soil + Equil (g)".

5. Add 10 mL of groundwater to each tube. Also add 10-mL groundwater to the "No-soil Controls. Record weight of each tube in "Tube + soils + Equil + GW (g)"
6. Add 74 µL 4-M NaOH to each tube. (See note 2 below)
7. Move rack of tubes to hood. Add 80 µL of radionuclide spike solution to each tube. Also add this to the No-soil Controls, Tube #139–141. Gently shake or swirl tube sediment and solution in each tube.
8. Using litmus paper, test the pH of a few samples (include a sandier sample and a clayey sample).
9. Leave samples in rad hood for 7 days.
10. Collect liquids by drawing liquids into a syringe and then passing liquid through a 0.45-µm filter.
11. Submit to Analytical Development Services for gamma spec analysis, Rush order.

[2] Initially, 64 µL of 4M NaOH was added to each tube. pH measured for tube #138 (sand) was ~3; pH for tube #130 (clay) was ~2-3. For tube #110 (clay), another 50 µL of 4M NaOH was added; pH was then ~12-13. For tubes #130 (clay) and #138 (sand), another 10 µL of of 4M NaOH was added; pH was ~5 for tube #130 and ~6 for tube #138. 100 µL of 1M HCl was added to tube #110 (clay) in an effort to bring down the pH; after the addition, pH was ~10. Based on these pH tests, it was decided to add 10 µL of 4M NaOH to the other tubes to make a total of 74 µL of 4M NaOH added to each tube (excluding tube #110).

Table 4. Raw Data Used to Calculate Kd values.

Method Step à Tube #	Soil	Rep.	Tube Tare (g) (2)	Soil (g) (3)	Tube + Soil + Equil (g) (4)	Tube + Soil + Equil + GW (g) (5)	Vol aq (mL)	Co-60 (dpm/mL)	Sr-85 (dpm/mL)	Cs-137 (dpm/mL)	Kd-Co (mL/g)	Kd-Sr (mL/g)		Kd-Cs (mL/g)
101	A-10[(a)]	1	5.4337	1.0040	7.0426	18.0492	11.6115	2.64E+02	1.58E+02	2.83E+01	2.0	8.9		52.0
102		2	5.4347	1.0069	7.0609	19.0076	12.5660	1.45E+02	1.05E+02	1.65E+01	14.1	17.5		60.5
103	C-7	1	5.4292	1.0075	6.7287	18.5227	12.0860	2.42E+02	1.51E+02	5.53E+01	3.3	10.5		20.9
104		2	5.4255	1.0034	6.8359	18.5910	12.1621	2.26E+02	1.59E+02	9.76E+01	4.5	7.5		8.7
105	D-10	1	5.4287	1.0047	6.7629	18.6484	12.2150	2.59E+02	1.61E+02	8.86E+01	2.4	8.1		10.5
106		2	5.4698	1.0083	6.8055	17.5641	11.0860	2.84E+02	1.65E+02	9.92E+01	1.0	7.5		9.3
107	E-7	1	5.4320	1.0006	7.4370	19.3070	12.8744	1.32E+02	5.59E+01	2.72E+01	17.2	44.2		18.1
108		2	5.4273	1.0072	7.4367	18.3745	11.9400	2.46E+02	1.60E+02	5.62E+01	3.0	7.2		21.8
109	E-12	1	5.4509	1.0029	7.1575	18.1105	11.6567	1.34E+02	5.17E+01	4.16E+01	15.3	51.7		10.7
110		2	5.4312	1.0093	7.1759	18.5948	12.1543	<1.96E+01	4.61E+01	<1.86E+01	178.2*	8.8*	>	23.8*
111	G-9	1	5.4666	1.0024	7.3660	19.3553	12.8863	1.86E+02	1.37E+02	4.67E+01	8.6	10.8		22.7
112		2	5.4292	1.0050	7.3397	18.2765	11.8423	1.92E+02	1.46E+02	<4.34E+01	7.2	8.8	>	28.2
113	J-11	1	5.4319	1.0021	7.0915	17.9914	11.5574	1.20E+02	1.45E+02	<3.06E+01	18.2	5.8	>	43.9
114		2	5.4266	1.0094	7.2076	19.1504	12.7144	1.82E+02	1.30E+02	<2.31E+01	8.8	12.7	>	51.0
115	K-10	1	5.4363	1.0028	6.8613	18.0527	11.6136	2.82E+02	1.45E+02	6.67E+01	1.1	14.2		15.6
116		2	5.4357	1.0088	6.8731	18.8209	12.3764	9.13E+01	1.36E+02	4.71E+01	29.3	5.8		23.0
117	L-7	1	5.4412	1.0034	7.0741	18.0311	11.5865	2.65E+02	1.45E+02	5.53E+01	2.0	12.9		20.6
118		2	5.4301	1.0039	6.9742	17.8678	11.4338	2.76E+02	1.56E+02	6.67E+01	1.4	9.9		17.0
119	M-5	1	5.4474	1.0072	6.9504	18.7299	12.2753	1.93E+02	1.68E+02	5.89E+01	7.4	4.5		21.0
120		2	5.4384	1.0087	6.9079	18.7930	12.3459	1.94E+02	1.30E+02	6.94E+01	7.3	14.1		12.7
121	N-3	1	5.4288	1.0039	6.8740	18.4855	12.0528	2.37E+02	1.54E+02	1.40E+02	3.7	9.2		3.4
122		2	5.4568	1.0030	7.4395	19.3039	12.8441	1.92E+02	1.32E+02	7.08E+01	7.9	12.1		12.2
123	P-8	1	5.4455	1.0066	6.7751	18.6811	12.2290	2.90E+02	1.62E+02	1.33E+02	0.8	8.7		4.2
124		2	5.4482	1.0075	6.7446	18.4503	11.9946	1.53E+02	1.58E+02	1.12E+02	12.2	5.2		6.5
125	Q-7	1	5.4316	1.0071	7.0935	19.0032	12.5645	2.59E+02	1.59E+02	9.27E+01	2.4	8.2		9.4
126		2	5.4331	1.0061	7.0440	17.9836	11.5444	2.30E+02	1.47E+02	5.78E+01	4.0	10.5		19.7
127	H-6	1	5.4483	1.0031	6.7404	17.5746	11.1232	<2.31E+01	1.63E+02	1.20E+02	137.6*	0.7*		5.9*
128		2	5.4612	1.0026	6.9664	18.0929	11.6291	2.77E+02	1.69E+02	1.44E+02	1.4	6.0		3.5

129	S-9	1	5.4393	1.0066	7.3046	18.2615	11.8156	2.40E+02	1.58E+02	7.36E+01	3.4	7.7		14.5
130		2	5.4476	1.0005	6.9939	17.9224	11.4743	2.52E+02	1.54E+02	5.17E+01	2.6	9.6		24.1
131	R-8	1	5.4281	1.0054	7.0576	17.9247	11.4912	2.75E+02	1.67E+02	1.29E+02	1.4	6.3		4.9
132		2	5.4359	1.0047	7.0935	18.0213	11.5807	2.51E+02	1.37E+02	5.04E+01	2.7	14.7		22.2
133	B-1003V-55-65	1	5.4504	1.0094	7.0474	18.9460	12.4862	1.82E+02	1.23E+02	3.53E+01	8.6	15.2		29.7
134		2	5.4323	1.0073	7.1057	18.9524	12.5128	1.50E+02	1.01E+02	<2.93E+01	13.2	19.6	>	30.5
135	B-1003V-65-75	1	5.4381	1.0052	6.8878	18.7720	12.3287	2.46E+02	1.30E+02	6.85E+01	3.2	18.0		12.9
136		2	5.4314	1.0030	6.9251	17.8039	11.3695	2.19E+02	1.41E+02	3.85E+01	4.7	12.1		32.6
137	B-1003V-75-82	1	5.4712	1.0009	7.0344	18.7090	12.2369	8.21E+01	8.40E+01	2.56E+01	33.9	15.4		30.1
138		2	5.5508	1.0056	7.0593	17.7241	11.1677	1.74E+02	1.26E+02	3.22E+01	8.7	13.5		36.4
139	No-soil control	1	5.4427			16.4855		3.10E+02	2.14E+02	2.13E+02				
140		2	5.4329			16.4129		2.98E+02	1.83E+02	1.90E+02				
141		3	5.4375			16.4830		3.21E+02	1.87E+02	1.88E+02				

* Suspect analytical results, this replicate not included in Kd calculations.

APPENDIX B. Analytics, Inc.'s Gamma-Ray Radionuclide Mixture Standard Used for Kd Measurements

SHIPPER'S DECLARATION

ANALYTICS
An Isotope Products Laboratories Company

1380 Seaboard Industrial Blvd.
Atlanta, Georgia 30318

Tel 404•352•8677
Fax 404•352•2837

www.analyticsinc.com

Shipment number 23409-13692 contains the following isotopes:

FORM: Liquid

RADIONUCLIDE	QUANTITY IN MICROCURIES*
Cd-109	2.0
Co-57	0.044
Ce-139	0.066
Hg-203	0.14
Sn-113	0.12
Cs-137	0.054
Y-88	0.20
Co-60	0.089
Am-241	0.15
Sr-85	0.15
TOTAL:	3.0

This package contains radioactivity that does not meet the definition of "Radioactive material" for transportation purposes (49CFR173.403, IATA 10.3.1).

SHIPPED TO: DOE
C/O WESTINGHOUSE SAVANNAH RIVER CO.

DATE: 5/3/6

*Quantities stated are approximate and for shipping purposes only. For certified quantities see Certificate of Calibration for each radioactive standard.

Ship. Dec. MIXED GAMMA

Corporate Office
24937 Avenue Tibbitts Valencia, California 91355

Laboratory
1380 Seaboard Industrial Blvd. Atlanta, Georgia, 30318

APPENDIX C. Gamma Spectroscopy Data

ADP FILE/NOTEBOOK REF	WSRC-NB-2003-00207 PAGE 50
Sample ID	300230592
Comment	counted 7/2/06

Nuclide	dpm/mL	1 Sigma Uncertainty
Co-57	9.90E+01	3.42%
Co-60	2.64E+02	2.45%
Sr-85	1.58E+02	3.59%
Y-88	1.38E+02	3.51%
CD-109	5.16E+03	4.18%
Cs-137	2.83E+01	11.7%
Ce-139	4.27E+01	7.18%
Hg-203	5.57E+01	5.91%
Am-241	1.71E+02	9.83%

Sample ID	300230593
Comment	counted 7/2/06

Nuclide	dpm/mL	1 Sigma Uncertainty
Co-57	5.53E+01	4.50%
Co-60	1.45E+02	3.12%
Sr-85	1.05E+02	4.28%
Y-88	4.18E+01	6.81%
Cd-109	3.21E+03	4.59%
Cs-137	1.65E+01	19.1%
Ce-139	1.15E+01	16.3%
Hg-203	3.85E+01	6.61%

Sample ID	300230594
Comment	counted 7/2/06

Nuclide	dpm/mL	1 Sigma Uncertainty
Co-57	8.82E+01	3.69%
Co-60	2.42E+02	2.47%
Sr-85	1.51E+02	3.56%
Y-88	1.38E+02	3.56%
Cd-109	4.74E+03	7.93%
Cs-137	5.53E+01	7.49%
Ce-139	4.25E+01	5.72%
Hg-203	4.81E+01	7.93%
Am-241	1.28E+02	14.0%

Sample ID	300230595
Comment	counted 7/2/06

Nuclide	dpm/mL	1 Sigma

		Uncertainty
CO-57	9.04E+01	3.46%
CO-60	2.26E+02	2.71%
SR-85	1.59E+02	3.41%
Y-88	2.27E+02	2.74%
CD-109	4.64E+03	4.24%
SN-126	4.53E+02	11.3%
CS-137	9.76E+01	5.16%
CE-139	7.71E+01	3.97%
HG-203	4.92E+01	6.36%
AM-241	2.49E+02	6.85%

Sample ID	300230596		
Comment	counted 7/2/06		
Nuclide	dpm/mL		1 Sigma Uncertainty
CO-57		1.01E+02	3.29%
CO-60		2.59E+02	2.48%
SR-85		1.61E+02	3.45%
Y-88		2.13E+02	2.93%
CD-109		5.02E+03	4.22%
CS-137		8.86E+01	5.55%
CE-139		6.92E+01	4.05%
HG-203		5.74E+01	6.09%
AM-241		2.45E+02	9.02%

Sample ID	300230597		
Comment	counted 7/2/06		
Nuclide	dpm/mL		1 Sigma Uncertainty
CO-57		1.07E+02	3.61%
CO-60		2.84E+02	2.37%
SR-85		1.65E+02	3.73%
Y-88		2.45E+02	2.69%
CD-109		5.60E+03	4.10%
CS-137		9.92E+01	5.51%
CE-139		8.34E+01	3.81%
HG-203		6.46E+01	5.81%
AM-241		2.71E+02	8.55%

Sample ID	300230598		
Comment	counted 7/2/06		
Nuclide	dpm/mL		1 Sigma Uncertainty
CO-57		9.16E+01	3.66%
CO-60		2.19E+02	2.70%
SR-85		1.32E+02	3.79%
Y-88		8.82E+01	4.48%

CD-109	4.50E+03	4.20%
CS-137	5.59E+01	6.94%
CE-139	2.72E+01	7.36%
HG-203	5.42E+01	5.82%
AM-241	8.86E+01	16.9%

Sample ID	300230599		
Comment	counted 7/2/06		
Nuclide	dpm/mL		1 Sigma Uncertainty
CO-57		9.66E+01	3.34%
CO-60		2.46E+02	2.46%
SR-85		1.60E+02	3.14%
Y-88		9.58E+01	4.41%
CD-109		5.09E+03	4.17%
CS-137		5.62E+01	7.71%
CE-139		2.86E+01	8.59%
HG-203		6.32E+01	4.96%
AM-241		9.47E+01	14.7%

Sample ID	300230600		
Comment	counted 7/3/06		
Nuclide	dpm/mL		1 Sigma Uncertainty
CO-57		9.44E+01	8.21%
CO-60		2.37E+02	5.88%
SR-85		1.34E+02	8.55%
Y-88		1.43E+02	7.94%
CD-109		4.97E+03	7.10%
CS-137		5.17E+01	21.5%
CE-139		4.16E+01	17.3%
HG-203		5.70E+01	15.4%
AM-241		1.22E+02	33.0%

Sample ID	300230601		
Comment	counted 7/3/06		
Nuclide	dpm/mL		1 Sigma Uncertainty
CO-57		<1.32E+01	MDA
CO-60		<1.96E+01	MDA
SR-85		4.61E+01	15.1%
CS-137		<1.86E+01	MDA

Sample ID	300230602		
Comment	counted 7/3/06		
Nuclide	dpm/mL		1 Sigma Uncertainty

CO-57	7.74E+01	9.27%
CO-60	1.86E+02	6.96%
SR-85	1.37E+02	7.86%
Y-88	8.87E+01	10.1%
CD-109	4.16E+03	7.42%
CS-137	4.67E+01	16.9%
CE-139	1.59E+01	31.4%
HG-203	5.86E+01	10.9%

Sample ID	300230603		
Comment	counted 7/3/06		
Nuclide	dpm/mL		1 Sigma Uncertainty
CO-57		8.65E+01	8.68%
CO-60		1.92E+02	7.65%
SR-85		1.46E+02	8.81%
Y-88		6.14E+01	20.6%
CD-109		4.22E+03	8.19%
Cs-137		<4.34E+01	MDA
HG-203		4.62E+01	18.0%

Sample ID	300230604		
Comment	counted 7/3/06		
Nuclide	dpm/mL		1 Sigma Uncertainty
CO-57		4.74E+01	14.6%
CO-60		1.20E+02	8.67%
SR-85		1.45E+02	7.79%
CD-109		3.14E+03	8.68%
Cs-137		<3.06E+01	MDA
HG-203		4.65E+01	17.6%

Sample ID	300230605		
Comment	counted 7/3/06		
Nuclide	dpm/mL		1 Sigma Uncertainty
CO-57		7.70E+01	9.38%
CO-60		1.82E+02	7.13%
SR-85		1.30E+02	8.20%
Y-88		6.84E+01	15.2%
CD-109		4.72E+03	7.04%
Cs-137		<2.31E+01	MDA
CE-139		1.69E+01	30.5%
HG-203		4.93E+01	14.3%

Sample ID	300230606
Comment	counted 7/3/06

Nuclide	dpm/mL		1 Sigma Uncertainty
CO-57		9.05E+01	8.87%
CO-60		2.82E+02	5.54%
SR-85		1.45E+02	8.41%
Y-88		1.67E+02	7.45%
CD-109		5.05E+03	6.68%
CS-137		6.67E+01	15.9%
CE-139		5.44E+01	13.7%
HG-203		5.87E+01	13.0%
		1.59E+02	30.8%

Sample ID	300230607
Comment	counted 7/3/06

Nuclide	dpm/mL		1 Sigma Uncertainty
CO-57		3.23E+01	18.6%
CO-60		9.13E+01	9.49%
SR-85		1.36E+02	8.60%
CD-109		3.11E+03	7.71%
CS-137		4.71E+01	16.4%
HG-203		4.65E+01	14.2%

Sample ID	300230608
Comment	counted 7/3/06

Nuclide	dpm/mL		1 Sigma Uncertainty
CO-57		9.03E+01	7.57%
CO-60		2.65E+02	5.68%
SR-85		1.45E+02	8.00%
Y-88		7.06E+01	13.1%
CD-109		5.03E+03	6.68%
CS-137		5.53E+01	16.8%
CE-139		2.00E+01	24.0%
HG-203		4.96E+01	13.2%

Sample ID	300230609
Comment	counted 7/3/06

Nuclide	dpm/mL		1 Sigma Uncertainty
CO-57		1.14E+02	7.47%
CO-60		2.76E+02	5.58%
SR-85		1.56E+02	7.71%
Y-88		1.53E+02	7.63%
CD-109		5.71E+03	6.33%
CS-137		6.67E+01	15.9%
CE-139		5.94E+01	12.3%
HG-203		6.31E+01	11.5%

Sample ID	300230610	
Comment	counted 7/3/06	
Nuclide	dpm/mL	1 Sigma Uncertainty
CO-57	8.94E+01	8.86%
CO-60	1.93E+02	6.53%
SR-85	1.68E+02	7.18%
Y-88	1.67E+02	7.55%
CD-109	4.38E+03	7.15%
CS-137	5.89E+01	18.8%
CE-139	5.87E+01	11.4%
HG-203	4.29E+01	15.4%
AM-241	1.81E+02	23.5%

Sample ID	300230611	
Comment	counted 7/3/06	
Nuclide	dpm/mL	1 Sigma Uncertainty
CO-57	8.27E+01	9.18%
CO-60	1.94E+02	6.65%
SR-85	1.30E+02	8.85%
Y-88	1.33E+02	8.28%
CD-109	4.00E+03	7.43%
CS-137	6.94E+01	14.2%
CE-139	3.97E+01	14.8%
HG-203	4.38E+01	15.1%
AM-241	1.21E+02	23.2%

Sample ID	300230612	
Comment	counted 7/3/06	
Nuclide	dpm/mL	1 Sigma Uncertainty
CO-57	9.70E+01	7.74%
CO-60	2.37E+02	6.18%
SR-85	1.54E+02	8.25%
Y-88	2.07E+02	6.39%
CD-109	5.34E+03	6.67%
CS-137	1.40E+02	9.60%
CE-139	6.46E+01	12.1%
HG-203	5.43E+01	13.6%
AM-241	1.65E+02	20.3%

Sample ID	300230613	
Comment	counted 7/3/06	
Nuclide	dpm/mL	1 Sigma

		Uncertainty
CO-57	8.14E+01	9.12%
CO-60	1.92E+02	6.55%
SR-85	1.32E+02	9.31%
Y-88	6.15E+01	13.1%
CD-109	4.10E+03	7.06%
CS-137	7.08E+01	14.0%
CE-139	2.50E+01	18.3%
HG-203	3.62E+01	19.5%

Sample ID	300230614
Comment	counted 7/3/06

Nuclide	dpm/mL	1 Sigma Uncertainty
CO-57	1.17E+02	7.89%
CO-60	2.90E+02	5.62%
SR-85	1.62E+02	7.74%
Y-88	2.76E+02	5.70%
CD-109	5.52E+03	6.25%
CS-137	1.33E+02	10.5%
CE-139	8.76E+01	11.7%
HG-203	4.87E+01	15.1%
AM-241	3.27E+02	14.9%

Sample ID	300230615
Comment	counted 7/3/06

Nuclide	dpm/mL	1 Sigma Uncertainty
CO-57	9.37E+01	8.43%
CO-60	2.67E+02	5.67%
SR-85	1.53E+02	8.68%
Y-88	2.89E+02	5.65%
CD-109	5.40E+03	6.97%
CS-137	1.58E+02	9.53%
CE-139	1.12E+02	8.22%
HG-203	5.11E+01	14.1%
AM-241	3.65E+02	12.9%

Sample ID	300230616
Comment	counted 7/3/06

Nuclide	dpm/mL	1 Sigma Uncertainty
CO-57	1.00E+02	8.49%
CO-60	2.59E+02	5.60%
SR-85	1.59E+02	8.02%
Y-88	2.51E+02	6.12%
CD-109	5.01E+03	6.70%

CS-137	9.27E+01	17.0%
CE-139	8.30E+01	8.08%
HG-203	5.30E+01	13.3%
AM-241	3.43E+02	14.1%

Sample ID	300230617		
Comment	counted 7/3/06		
Nuclide	dpm/mL		1 Sigma Uncertainty
CO-57		8.93E+01	7.63%
CO-60		2.30E+02	6.01%
SR-85		1.47E+02	8.05%
Y-88		1.48E+02	8.12%
CD-109		5.06E+03	6.30%
CS-137		5.78E+01	14.9%
CE-139		5.56E+01	12.2%
HG-203		4.62E+01	16.3%
AM-241		1.69E+02	25.2%

Sample ID	300230618		
Comment	counted 7/3/06		
Nuclide	dpm/mL		1 Sigma Uncertainty
Co-57		<1.30E+01	MDA
Co-60		<2.31E+01	MDA
SR-85		1.63E+02	6.95%
CS-137		1.20E+02	9.79%

Sample ID	300230619		
Comment	counted 7/3/06		
Nuclide	dpm/mL		1 Sigma Uncertainty
CO-57		1.05E+02	7.79%
CO-60		2.77E+02	5.62%
SR-85		1.69E+02	7.80%
Y-88		3.24E+02	5.22%
CD-109		5.26E+03	6.81%
CS-137		1.44E+02	10.1%
CE-139		1.11E+02	7.23%
HG-203		6.45E+01	13.9%
AM-241		3.61E+02	15.3%

Sample ID	300230620		
Comment	counted 7/3/06		
Nuclide	dpm/mL		1 Sigma Uncertainty
CO-57		1.01E+02	8.25%

CO-60	2.40E+02	5.95%
SR-85	1.58E+02	7.85%
Y-88	1.94E+02	7.03%
CD-109	5.10E+03	6.11%
CS-137	7.36E+01	14.3%
CE-139	6.21E+01	11.9%
HG-203	4.11E+01	16.8%
AM-241	2.30E+02	18.5%

Sample ID	300230621		
Comment	counted 7/3/06		
Nuclide	dpm/mL		1 Sigma Uncertainty
CO-57		1.02E+02	7.75%
CO-60		2.52E+02	5.79%
SR-85		1.54E+02	7.71%
Y-88		9.81E+01	10.9%
CD-109		5.17E+03	6.17%
CS-137		5.17E+01	19.2%
CE-139		3.53E+01	20.4%
HG-203		6.85E+01	12.4%

Sample ID	300230622		
Comment	counted 7/3/06		
Nuclide	dpm/mL		1 Sigma Uncertainty
CO-57		1.02E+02	7.36%
CO-60		2.75E+02	5.71%
SR-85		1.67E+02	7.53%
Y-88		2.95E+02	5.73%
CD-109		5.10E+03	7.23%
CS-137		1.29E+02	10.8%
CE-139		1.10E+02	7.02%
HG-203		5.13E+01	14.2%
AM-241		2.86E+02	13.5%

Sample ID	300230623		
Comment	counted 7/3/06		
Nuclide	dpm/mL		1 Sigma Uncertainty
CO-57		1.00E+02	7.18%
CO-60		2.51E+02	5.61%
SR-85		1.37E+02	8.98%
Y-88		8.02E+01	12.0%
CD-109		4.73E+03	6.96%
CS-137		5.04E+01	18.1%
CE-139		2.58E+01	20.6%
HG-203		6.45E+01	12.8%

Sample ID	300230624	
Comment	counted 7/3/06	
Nuclide	dpm/mL	1 Sigma Uncertainty
CO-57	7.08E+01	8.43%
CO-60	1.82E+02	7.15%
SR-85	1.23E+02	8.52%
Y-88	9.70E+01	12.8%
CD-109	4.42E+03	6.52%
CS-137	3.53E+01	23.1%
CE-139	2.95E+01	17.2%
HG-203	4.91E+01	13.2%

Sample ID	300230625	
Comment	counted 7/3/06	
Nuclide	dpm/mL	1 Sigma Uncertainty
CO-57	6.09E+01	9.90%
CO-60	1.50E+02	7.48%
SR-85	1.01E+02	9.97%
CD-109	3.91E+03	6.76%
Cs-137	<2.93E+01	MDA
HG-203	5.17E+01	14.3%

Sample ID	300230626	
Comment	counted 7/3/06	
Nuclide	dpm/mL	1 Sigma Uncertainty
CO-57	9.16E+01	7.10%
CO-60	2.46E+02	6.14%
SR-85	1.30E+02	8.83%
Y-88	1.10E+02	9.49%
CD-109	4.44E+03	16.7%
CS-137	6.85E+01	14.2%
CE-139	3.02E+01	13.6%
HG-203	5.12E+01	14.0%

Sample ID	300230627	
Comment	counted 7/3/06	
Nuclide	dpm/mL	1 Sigma Uncertainty
CO-57	8.92E+01	6.76%
CO-60	2.19E+02	6.65%
SR-85	1.41E+02	8.22%
Y-88	5.99E+01	17.6%
CD-109	5.46E+03	6.33%

CS-137	3.85E+01	19.0%
CE-139	1.61E+01	22.8%
HG-203	5.92E+01	10.7%

Sample ID	300230628		
Comment	counted 7/3/06		
Nuclide	dpm/mL		1 Sigma Uncertainty
CO-57		2.65E+01	13.8%
CO-60		8.21E+01	10.5%
SR-85		8.40E+01	10.4%
CD-109		1.69E+03	11.3%
CS-137		2.56E+01	23.6%
HG-203		3.34E+01	18.0%

Sample ID	300230629		
Comment	counted 7/3/06		
Nuclide	dpm/mL		1 Sigma Uncertainty
CO-57		7.09E+01	9.31%
CO-60		1.74E+02	7.52%
SR-85		1.26E+02	8.19%
CD-109		4.66E+03	6.48%
CS-137		3.22E+01	22.7%
HG-203		6.03E+01	12.1%

Sample ID	300230630		
Comment	counted 7/3/06		
Nuclide	dpm/mL		1 Sigma Uncertainty
CO-57		1.19E+02	6.89%
CO-60		3.10E+02	5.53%
SR-85		2.14E+02	6.94%
Y-88		3.56E+02	5.57%
CD-109		6.06E+03	6.84%
CS-137		2.13E+02	8.47%
CE-139		1.36E+02	6.40%
HG-203		7.13E+01	13.2%
AM-241		6.78E+02	12.5%

Sample ID	300230631		
Comment	counted 7/3/06		
Nuclide	dpm/mL		1 Sigma Uncertainty
CO-57		1.36E+02	5.59%
CO-60		2.98E+02	6.13%
SR-85		1.83E+02	7.34%

Y-88	3.69E+02	5.24%
CD-109	5.87E+03	6.55%
CS-137	1.90E+02	9.09%
CE-139	1.44E+02	6.00%
HG-203	5.77E+01	13.4%
AM-241	4.36E+02	14.8%

Sample ID	300230632		
Comment	counted 7/3/06		
Nuclide	dpm/mL		1 Sigma Uncertainty
CO-57		1.27E+02	6.40%
CO-60		3.21E+02	5.74%
SR-85		1.87E+02	7.44%
Y-88		3.55E+02	5.34%
CD-109		5.70E+03	6.86%
CS-137		1.88E+02	9.21%
CE-139		1.41E+02	7.38%
HG-203		6.93E+01	12.1%
AM-241		4.08E+02	16.6%

APPENDIX D. Correlation Coefficients between Kd Values and Sediment Properties

Table 5. Correlation Coefficients between Kd Values and Sediment Properties.

Parameters	Kd Co	Kd Sr	Kd Cs	CEC	%Clay	%Fines
Kd Co						
Kd Sr	**0.93***					
Kd Cs	0.21	-0.11				
CEC	-0.09	-0.03	0.29			
%Clay	-0.47	-0.55	0.44	0.76		
%Fines	0.25	0.22	0.48	**0.89***	0.70	
pH (DI water)	0.46	0.12	0.76	0.02	-0.09	0.02

*r critical at P <0.05 n = 4 is 0.811, indicating significant correlation.
Fines = clay + silt

APPENDIX E. Groundwater Characterization

Table 6. Groundwater Characterization (Duplicate, A&B).

	Vogtle-1 (A) 06-1331 (mg/L)	Vogtle-1 (B) 06-1331 (mg/L)		Vogtle-1 (A)	Vogtle-1 (B)
F	**<1.00**	**<1.00**	**pH**	**10.8**	**11.0**
Cl	**1.82**	**1.83**			
NO_2	**<1.00**	**<1.00**			
NO_3	**8.32**	**8.34**			
SO_4	**6.37**	**6.39**			
PO_4	**<1.00**	**<1.00**			
	Vogtle-1 (A) (mg/L)	**Vogtle-1 (B) (mg/L)**		**Vogtle-1 (A) (mg/L)**	**Vogtle-1 (B) (mg/L)**
Al	**2.56**	**2.63**	**Mg**	**<0.010**	**<0.010**
Ba	**<0.010**	**<0.010**	**Mn**	**<0.010**	**<0.010**
Ca	**24.7**	**24.6**	**Na**	**12.2**	**12.1**
Cd	**<0.010**	**<0.010**	**Ni**	**<0.010**	**<0.010**
Co	**<0.010**	**<0.010**	**P**	**0.064**	**0.063**
Cr	**<0.010**	**<0.010**	**Pb**	**<0.010**	**<0.010**
Cu	**<0.010**	**<0.010**	**S**	**2.28**	**2.13**
Fe	**<0.010**	**<0.010**	**Si**	**10.0**	**9.50**
K	**16.7**	**16.8**	**Sn**	**<0.100**	**<0.100**
Li	**<0.500**	**<0.500**	**Sr**	**0.592**	**0.554**
			Zn	**<0.010**	**<0.010**
Total Dissolved Solids				**0.0330**	**0.0328**

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