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REPORT

APPENDIX D.3

URANIUM PARTITION COEFFICIENT EVALUATION STUDY

D.3.0 URANIUM PARTITION COEFFICIENT EVALUATION STUDY

This appendix documents the results of the Uranium Partition Coefficient Evaluation Study carried out in support of the Remedial Investigation/Feasibility Study (RI/FS) for Operable Unit 2 - Other Waste Units at the U.S. Department of Energy (DOE), Fernald Environmental Management Project (FEMP) at Fernald, Ohio. The study consisted of laboratory analyses conducted to determine the partition coefficients (K_d) for waste, soils, and geologic formations in Operable Unit 2 as an input in fate and transport modeling. This appendix will focus on the K_d for total uranium, which is prevalent throughout the Operable Unit 2 waste units. The K_d results are based on both adsorption and desorption tests conducted at the FEMP laboratory.

To identify Operable Unit 2-specific K_d values, a laboratory study was conducted on Operable Unit 2 waste and soil. Waste and soil samples were collected from the waste units and associated geological layers for each of the subunits. These waste or soil samples underwent laboratory tests in which they were mixed with a leachate solution in a batch-type reactor. Two separate tests were conducted: one test evaluated the amount of uranium that was leached from the waste and soil, and the other test evaluated the amount of uranium that was adsorbed by the waste or soil. The first test was conducted on samples (collected in the subunits where the media was contaminated) that were considered to be contaminated. The second test was conducted on samples which analysis showed had little or no contamination.

D.3.1 Soil Sample Selection

Table D.3-1 is a summary of the samples which were used to develop K_d values and the location where they were sampled. The samples were collected from the ongoing field sampling activities or retrieved from the FEMP sample archives. The contaminated samples were identified by the beta-gamma field readings conducted during the field sampling program. Samples with beta-gamma field readings above background were considered contaminated. Once the appropriate sample(s) were located, sample numbers were identified for retrieval from FEMP archives. Since the RI field sampling program was in progress at the time, some soil samples were collected directly from the field.

TABLE D.3-1

SUMMARY OF K_d STUDY SAMPLES FOR OPERABLE UNIT 2

Waste Subunits	Waste Material Samples	Glacial Overburden Samples	Sand and Gravel Samples	Great Miami Aquifer Samples
Solid Waste Landfill	Boring 1985 (depth 0-3 ft.) Boring 1986 (depth 5-7.5 ft.)	Boring 1986 (depth 12.5-15 ft.) Boring 11037 (depth 20-22.5 ft.)	Boring 2953 (depth 46 ft.)	Boring 2953 (depth 70 ft.)
Lime Sludge Ponds	LSP-SS-03 (depth 0-12 in.) LSP-SS-05 (depth 0-6 in.) LSP-SS-06 (depth 0-6 in.)	N/S[a]	N/S	N/S
Inactive Flyash Pile	Boring 11001 (depth 0.5-2.5 ft.) Boring 11003 (depth 3.5-5.5 ft.)	N/S	N/S	N/S
Active Flyash Pile	Boring 1980 (depth 4-5.5 ft.)	N/S	N/S	N/S
South Field	Trench No. 1 (depth 2 ft.)	Boring 11187 (depth 6.5-7 ft.) Trench No. 4 (depth 7 ft.)	Boring 2944 (depth 25-51 ft.)	Boring 2944 (depth 50-65 ft.)

[a]N/S = no sample collected.

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The main purpose for collecting samples directly from the field was to ensure that samples with significant levels of contamination were used. The field samples included both Trench Nos. 1 and 4 samples in the South Field; Boring No. 1985 in the Solid Waste Landfill; and the sand and gravel samples from Boring No. 2944 in the South Field and Boring No. 2953 in the Solid Waste Landfill. The samples with the highest contamination based on hand-held beta-gamma measurements were found in the South Field trench locations and at Boring No. 1985 in the Solid Waste Landfill. The sand and gravel samples from Boring Nos. 2944 and 2953 were collected because the samples were the last two borings to be drilled in the RI sampling program, and all the previous borings contained low concentrations in the sand and gravel zones. After collection, however, these samples also showed no or little contamination.

The sample volume required for the test was approximately two liters; however, the archive samples were usually in 500 milliliter (mL) jars. Therefore, three to four archive samples were required at slightly different depths to make one K_d sample. However, all of the samples were from the same split spoon interval, with the exception of samples from Boring No. 2944. Samples from Boring No. 2944 in the South Field were collected over a 7.9 m (26 ft) interval and a 4.6 m (15 ft) interval for the unsaturated and saturated sand and gravel, respectively. These samples were composited in the field, whereas the archive samples were combined and homogenized in the FEMP laboratory.

D.3.1.1 Waste Samples

A waste material sample was collected from each subunit. All were identified as containing elevated levels of uranium, except the Active Flyash Pile sample. The waste material was considered the flyash for the Active Flyash Pile and the Inactive Flyash Pile. One sample from each pile was collected. A second sample at the Inactive Flyash Pile was collected for the earthen cover material overlying the flyash. The waste material at the Lime Sludge Pond was the lime sludge. Two samples were taken at the north Lime Sludge Pond and composited into one. Another sample of the earthen berm material was also collected.

Two waste samples were collected for the Solid Waste Landfill. Both were in the boundaries of the waste cells and were taken at different depths. Two waste material samples were collected for the South Field. The samples were collected during the RI trenching at the South Field; visual inspection identified the samples as fill material. Sample No. 113721 was taken at a depth of approximately 1.8 m (6 ft) in Trench No. 4 where the fill appeared to transition to natural till.

D.3.1.2 Glacial Overburden Layer

The glacial overburden was characterized using soil samples collected from two separate areas composed of Operable Unit 2 subunits. The areas were the Solid Waste Landfill/Lime Sludge Ponds and the Active Flyash Pile/Inactive Flyash Pile/South Field. This approach was based on similarities in lithologic descriptions taken from boring logs from each collection area. Additionally, the South Field and the Solid Waste Landfill were considered to have the greatest potential for future impact to the Great Miami Aquifer. All of the glacial overburden samples collected for the study were contaminated.

Two samples were collected from Solid Waste Landfill: one in a blue clay just below the bottom of the Solid Waste Landfill at a depth of 3.8 to 4.6 m (12.5 to 15.0 ft) and the other in an olive clay area below the blue clay at a depth of 6.1 to 6.9 m (20 to 22.5 ft). One sample was collected from the South Field at Boring No. 1974 in a light olive brown silty clay at a depth of 21 m (7 ft).

D.3.1.3 Sand and Gravel Layer

The sand and gravel samples were considered to be similar at all the subunits. This approach was based on the Great Miami Aquifer being continuous over the site. All the sand and gravel samples collected for the K_d study were relatively free of contamination. The samples were collected at two locations. One set of samples (saturated and unsaturated) was collected at the Solid Waste Landfill/Lime Sludge Ponds in an area between the two units. The other set of samples was collected in the South Field.

D.3.2 Laboratory Procedures

Two types of batch tests were used to perform the laboratory K_d studies. One was a desorption test used on the contaminated samples and was based on determining the amount of total uranium that leached into solution. The other was an adsorption test used on the samples which contained low concentrations of total uranium and was based on determining the total uranium adsorbed by the soil/waste from a uranium spiked water solution. The desorption and adsorption tests meet the same objectives but operate in reverse of one another. Both tests will determine the equilibrium uranium concentrations of the soil and liquid solution. The selection of the appropriate K_d test was based on the soil sample's initial total uranium concentration. A total of 19 tests were performed on the soil samples, which consisted of 11 desorption tests and 8 adsorption tests.

The desorption test was performed for all of the samples that had a total uranium concentration above background. The adsorption test was performed on the remaining soil samples. For some samples, both the adsorption and desorption tests were performed for comparison purposes. A total uranium analysis on the initial waste/soil samples was performed by both the FEMP and International Technology Corporation Analytical Services (ITAS), which participates in the U.S. Environmental Protection Agency's (EPA) Contract Laboratory Program (CLP).

The American Society for Testing and Materials (ASTM) D 4319-83 Standard Test Method for Distribution Ratios by the Short-Term Batch Method was evaluated and used as guidance in the preparation of the procedure used in the K_d evaluation. Where appropriate, specific preparatory procedures of the ASTM were used. The K_d evaluation procedure is provided in Attachment D.3-I.

D.3.2.1 Desorption Test

In general, the desorption test consisted of placing a 400-gram portion of the sample into a 1-gallon Nalgene plastic jar/reactor with 3,500 mL of a water solution. This equated to a liquid-to-soil ratio of 8.75. The soil and liquid mixture was tumbled continuously at approximately 29 revolutions per minute until the total uranium concentration in the water solution reached equilibrium.

Soil preparation started with compositing several archive samples for the same boring and depth (due to the small volumes archived) into a 600-gram sample. The 600-gram sample was then filtered to remove any free liquids. No drying was performed. The only samples requiring filtering were the saturated sand and gravel samples. After filtering, a 400-gram sample was weighed and placed in a reactor with the water.

The remaining portion of the waste/soil sample that was not placed in the jar was prepared for laboratory analysis on total uranium and moisture content. A 200-gram sample was oven dried at 103°C for 24 hours. The moisture content was calculated by using the weight of the sample before oven drying and the weight of the sample after oven drying. A 10-gram portion of the oven dried sample was used for the FEMP total uranium analysis and a 135-gram portion was used for the off-site laboratory analysis.

In the desorption tests, three different water solutions were used with the soils to determine the K_d and were based on the location/type of the soil sample. For the waste material samples, a

distilled-water solution adjusted to 5.6 pH with a 60/40 mixture of sulfuric acid to nitric acid solution was used. This water solution was used to represent the rainwater percolating through the waste material. The glacial overburden soil samples used a distilled-water solution with no pH adjustment. The unsaturated and saturated sand and gravel samples were mixed with FEMP groundwater from a 3000- series background well. The groundwater was considered to have a uranium concentration that was representative of the background level at the site.

The time period for the desorption test samples to reach equilibrium was approximately 2 weeks. During each test, a sample of the water solution was periodically analyzed for total uranium to verify when the sample reached equilibrium. This was performed by drawing off 20 mL of leachate and filtering the sample through a 0.45 micron size membrane filter to remove any solids. The sampling frequency for some of the water samples was adjusted on occasion because of holidays or weekends. All of the intermediate water samples were analyzed for total uranium at the FEMP laboratory to allow quick turnaround times which were required during the test. The final samples from each test were split between the ITAS and FEMP laboratory.

Other parameters such as pH, oxidation/reduction potential (E_h), and specific conductivity can effect the "sorption" process and K_d value (ASTM D-4319). Therefore, during each adsorption/desorption test, periodic measurements were made for temperature, pH, E_h, and specific conductivity. The measurements were made at the same time that samples of the water solutions were collected for total uranium analysis during the test.

All of the subunits' waste samples and glacial overburden samples underwent the desorption test, except for the Active Flyash Pile flyash. The Active Flyash Pile flyash was not contaminated above background concentrations. Also, the Inactive Flyash Pile flyash sample did not leach uranium at concentrations which were detectable, and, therefore, was discontinued after ten days. Attachment D.3.II provides the laboratory desorption test results.

D.3.2.2 Adsorption Test

In the adsorption test, the same type of water solutions were prepared as in the desorption tests, depending on the location of the sample. The exception in the preparation activities between the two tests was that the water solutions were spiked with uranium for the adsorption test. The spiked solution was a 1.0 mg/mL concentration of uranium nitrate in 2 percent nitric acid. The water was

spiked with 7 mL of the uranium nitrate solution. The addition of the uranium nitrate solution resulted in a uranium concentration of 2 mg/L for the initial water solution in all of the adsorption tests.

The testing period on the adsorption of non-contaminated samples focused more on the first 72 hours of the test. During this period, a sample was collected each day. Literature review indicates most adsorption tests reach equilibrium within that time period (ASTM D-4319). If equilibrium was not reached, periodic sampling would continue after the 72-hour period until equilibrium was reached. Equilibrium was determined by evaluating results from two consecutive samples. If the samples were within 5 percent (+ or -) or less, the sample was considered at equilibrium, and the test was stopped.

All of the sand and gravel samples underwent the adsorption test, since they were not contaminated. The soil samples from the glacial overburden at Boring No. 1986 in the Solid Waste Landfill, flyash at both the Active Flyash Pile and Inactive Flyash Pile, and Trench No. 4 in the South Field were also tested. These soil samples, except for the Active Flyash Pile flyash, had total uranium concentrations which were considered too low to leach into solution under the desorption test. The desorption test was performed on these three samples, with the adsorption test performed for comparison purposes. The flyash sample from the Inactive Flyash Pile (Sample No. 114068) did not leach any measurable quantity of uranium during the desorption test. The other two glacial overburden samples (Sample Nos. 111457 and 113721) had detectable uranium concentrations in the leachate. Attachment D.3.III provides the laboratory adsorption test results.

D.3.2.3 Analytical Methods/Procedures

The total uranium analysis was performed by both the FEMP laboratory and the ITAS. The FEMP analysis was at an analytical support level B and the ITAS analysis was at an analytical support level C. The FEMP laboratory used calorimetric analysis for the soil analysis and laser phosphorimetry for the water analysis. The volume requirements were 5 grams for the soils and 10 mL for the water. The FEMP Analytical Laboratory Services methods used were 3002 and 3062 for soils and water, respectively, which is consistent with the FEMP Site-Wide Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) Quality Assurance Project Plan requirements.

The ITAS used gamma spectrometry for the soil analysis and pulsed laser phosphorimetry for the water analysis. The volume requirements were 135 grams for the soils and 210 mL for the water. The standard operating procedures used were OR7003 and OR7127 for soils and water, respectively, and was consistent with the EPA-approved CLP operating procedures.

The pH, E_h, conductivity, and temperature were measured by placing the instrument probe directly into the jar/reactor. The instrument was calibrated each day for E_h, conductivity, and pH. The E_h and conductivity calibration was performed by zeroing the meter. The pH was calibrated by using a 4.0 and 7.0 pH buffer. Also, when using the probe, the jars were organized to be sampled in increasing aqueous uranium concentrations; the probe was also raised with deionized water between samples to avoid cross-contamination of the samples.

D.3.3 Partition Coefficient Calculations

The K_d values for both the adsorption and desorption tests were calculated by dividing the concentration of uranium in the test media or soil (at equilibrium) by the concentration of uranium in the test liquid or groundwater (at equilibrium), as follows:

$$K_d = \frac{C_s'}{C_l} \qquad \text{(D.3-1)}$$

where

C_s' = concentration of uranium in soil or test media (minus background)

C_l = concentration of uranium in liquid (at equilibrium)

The concentration of uranium in the liquid (at equilibrium) was obtained directly from laboratory analytical results; however, the concentration of uranium in the soil was calculated.

Desorption Calculations:

In order to calculate the concentration of uranium in the soil (at equilibrium), the mass of uranium in the water (at equilibrium) must first be determined. The mass of uranium was calculated by multiplying the concentration of uranium in the liquid (at equilibrium) by the total volume of the test liquid used during the desorption test, as follows:

$$m_l = C_l \times V \qquad \text{(D.3-2)}$$

where

m_l = mass of uranium in liquid (at equilibrium)

V = volume of liquid used during desorption testing

The initial mass of uranium in the soil was calculated by multiplying the initial concentration of uranium in the soil by the mass of the soil, as follows:

$$m_s = C_o \times M \qquad \text{(D.3-3)}$$

where

m_s = initial mass of uranium in soil or test media

C_o = initial concentration of uranium in soil or test media

M = mass of soil or test media

Once these two values were determined, the concentration of uranium in the soil (at equilibrium) was calculated by subtracting the mass of uranium in the liquid (at equilibrium) from the initial mass of uranium in the soil and dividing the difference by the mass of the soil, as follows:

$$C_s = \frac{m_s - m_l}{M} \qquad \text{(D.3-4)}$$

where

C_s = concentration of uranium in soil or test media (at equilibrium)

In calculating the K_d values, the liquid source has an impact on determining the total uranium concentration in the soil. The background uranium concentration in soil was assumed to be in equilibrium with groundwater. In tests where groundwater was used as the desorption test liquid, the background uranium concentration was not subtracted from the concentration of uranium in the soil (at equilibrium); therefore, C_s' equals C_s. However, in tests where groundwater was not used as the adsorption test liquid, the background uranium concentration was subtracted from the concentration of uranium in the soil (at equilibrium), as follows:

$$C_s' = C_s - C_b \qquad \text{(D.3-5)}$$

where

C_b = background concentration of uranium

The background total uranium concentration in soil was calculated to be 3.7 micrograms per gram (μg/g) by using the FEMP background activity for uranium isotopes. The equation used for the calculation is found in Data Validation Program, Rev. 0, DOE Oak Ridge Operations Office, 1991, pages D-3 through D-5.

The K_d calculations for the desorption tests were based on the analytical results for the ITAS laboratory and can be found in Attachment D.3-IV. A summary of the off-site analytical results and the K_d values for the desorption tests are provided in Table D.3-2.

Desorption Test Calculation Example:

The following is an example of desorption testing calculations for Sample No. 111457 to determine the K_d value.

C_o = 18.3 μg/g
C_l = 10.6 μg/L
M = 400 g
V = 3.5 L
C_b = 3.7 μg/g
m_l = C_l x V = 10.6 μg/L x 3.5 l = 37.1 μg
m_s = C_o x M = 18.3 μg/g x 400 g = 7,320 μg

$$C_s = \frac{m_s - m_l}{M} = \frac{7{,}320\ \mu g - 37.1\ \mu g}{400\ g} = \frac{7282.9\ \mu g}{400\ g} = 18.2\ \mu g/g$$

$$C_s' = C_s - C_b = 18.2\ \mu g/g - 3.7\ \mu g/g = 14.5\ \mu g/g$$

$$K_d = \frac{C_s'}{C_l} = \frac{14.5\ \mu g/g}{10.6\ \mu g/L} = 1.37\ L/g = 1370\ L/kg$$

$$K_d = 1370\ L/kg$$

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TABLE D.3-2
OPERABLE UNIT 2 K_d VALUES FOR DESORPTION TEST

Sample No.	Location[a]	Total Uranium			K_d Values (L/kg)
		Initial Soil Concentration (μg/g)	Equilibrium Soil Concentration (μg/g)	Equilibrium Water Concentration (μg/L)	
111455	Solid Waste Landfill/1986 - Waste Material	146.0	127.4	1700.0	75
111440	Solid Waste Landfill/1985 - Waste Material	74.0	63.9	726.0	88
111457	Solid Waste Landfill/1986 - Glacial Overburden	18.3	14.5	10.6	1370
115370	Solid Waste Landfill/11037 - Glacial Overburden	9.0/2.65[b]	2.0	10.0	200
114472	Lime Sludge Pond/SS03 - Waste/Berm Material	18.9	14.8	41.6	360
114494	Lime Sludge Pond/SS05&06 - Lime Sludge	14.3	10.6	4.0	2650
114067	Inactive Flyash Pile/11001 - Cover Material	147.0	127.5	1810.0	70
114068	Inactive Flyash Pile/11003 - Flyash	16.9	---[c]	---	---
114070	South Field/11187 - Glacial Overburden	308.0	304	32.5	9350
113717	South Field/Trench No. 1 - Waste Material	278.0	261.4	1480.0	180
113721	South Field/Trench No. 4 - Waste Material	4.34	0.6	2.16	280

[a]Identifies subunit and boring number

[b]Used average of FEMP and IT soil concentration

[c]Concentration below detection limit

Adsorption Calculations:

In order to calculate the concentration of uranium in the soil (at equilibrium), the amount of uranium adsorbed to the soil must first be calculated. The mass of uranium adsorbed was calculated by multiplying the initial concentration of uranium spiked in the liquid by the volume of the liquid used during adsorption testing, as follows:

$$m_i = S \times V \qquad \text{(D.3-6)}$$

where

m_i = initial mass of uranium spiked in liquid

S = initial concentration of uranium spiked in liquid

V = volume of liquid used during adsorption testing

Then, the mass of uranium in the solution (at equilibrium) was calculated by multiplying the concentration of uranium in the liquid (at equilibrium) by the volume of the liquid used during adsorption testing, as follows:

$$m_f = C_l \times V \qquad \text{(D.3-7)}$$

where

m_f = mass of uranium in liquid (at equilibrium)

C_l = concentration of uranium in liquid (at equilibrium)

The concentration of uranium adsorbed in the soil was calculated by subtracting the mass of uranium in the liquid (at equilibrium) from the initial mass of uranium spiked in the liquid and dividing the difference by the total soil mass, as follows:

$$C_a = \frac{m_i - m_f}{M} \qquad \text{(D.3-8)}$$

where

C_a = concentration of uranium adsorbed in soil or test media

M = mass of soil or test media

The final concentration of uranium in the soil (at equilibrium) was calculated by adding the concentration of uranium adsorbed in the soil to the initial concentration of uranium in the soil, as follows:

$$C_s = C_a + C_o \qquad \text{(D.3-9)}$$

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where

C_s = concentration of uranium in soil or test media (at equilibrium)
C_o = initial concentration of uranium in soil or test media

The background uranium concentration in the soil was assumed to be in equilibrium with the groundwater concentrations; therefore, in tests where groundwater was used as the adsorption test liquid, the background uranium concentration was not subtracted from the concentration of uranium in the soil (at equilibrium); therefore, Cs' equals Cs. In tests where groundwater was not used as the adsorption test liquid, the background uranium concentration was subtracted from the concentration of uranium in the soil (at equilibrium), as follows:

$$C_s' = C_s - C_b \qquad \text{(D.3-10)}$$

where

C_b = background concentration of uranium

The K_d calculations for the adsorption tests were based on the analytical results for the ITAS laboratory and can be found in Attachment D.3-V. A summary of the off-site analytical results and the K_d values for the adsorption test are provided in Table D.3-3.

Adsorption Test Calculation Example:

The following is an example of adsorption testing calculations for Sample No. 11457 to determine the K_d values.

Given:

C_o = 18.3 μg/g
C_l = 357 μg/L
M = 400 g
V = 3.5 L
S = 2000 μg/L

Calculations:

m_i = S x V = 2000 μg/L x 3.5 L = 7000 μg
m_f = C_l x V = 357 μg/L x 3.5 L = 1249.5 μg

$$C_a = \frac{m_i - m_f}{M} = \frac{7000\ \mu g - 1249.5\ \mu g}{400\ g} = \frac{5750.5\ \mu g}{400\ g} = 14.4\ \mu g/g$$

TABLE D.3-3
OPERABLE UNIT 2 K_d VALUES FOR ADSORPTION TEST

Sample No.	Location[a]	Total Uranium			K_d Values (L/kg)
		Initial Soil Concentration (μg/g)	Equilibrium Soil Concentration (μg/g)	Equilibrium Water Concentration (μg/L)	
115445	Solid Waste Landfill/2953 - Unsaturated Sand and Gravel	1.63	11.1	918.0	12.0
115454	Solid Waste Landfill/2953 - Saturated Sand and Gravel	1.17	10.1	982.0	10.0
111457	Solid Waste Landfill/1986 - Glacial Overburden	18.3	29.0	357.0	81
114068	Inactive Flyash Pile/11003 - Flyash	16.9	30.7	3.0[b]	10,230
114069	Active Flyash Pile/1980 - Flyash	12.2	21.1	564.0	37.0
113721	South Field/Trench No. 4 - Waste Material	4.34	10.4	876.0	12.0
113755	South Field/2944 - Unsaturated Sand and Gravel	1.43	11.7	826.0	14.0
113770	South Field/2944 - Saturated Sand and Gravel	2.86	9.9	1190.0	8.0

[a]Identifies subunit and boring number

[b]Used FEMP average water analysis result

$$C_s = C_a + C_o = 14.4\ \mu g/g + 18.3\ \mu g/g = 32.7\ \mu g/g$$

$$C_{s'} = C_s - C_b = 32.7\ \mu g/g - 3.7\ \mu g/g = 29.0\ \mu g/g$$

$$K_d = \frac{C_{s'}}{C_l} = \frac{29.0\ \mu g/g}{357\ \mu g/L} = 0.081\ L/g = 81.0\ L/kg$$

$$K_d = 81.0\ L/kg$$

The off-site results were used, because they were performed by a laboratory using EPA CLP procedures.

D.3.4 Summary and Conclusions

This section presents the K_d values that were calculated for all tests, and discusses the significance of these test results.

D.3.4.1 Desorption Versus Adsorption

A summary of K_d values for desorption and adsorption tests is provided in Table D.3-4. Two values were provided wherever there were two samples from the same area, and for the sand and gravel samples since they were similar. The K_d values, based on desorption values, were significantly higher then the adsorption test based K_d values. Results for Solid Waste Landfill Sample No. 111457 and South Field Sample No. 113721 provide a direct comparison between the two tests. Measurement of the Solid Waste Landfill sample yielded a K_d of 1,370.0 L/kg from the desorption test and a K_d of 81.0 L/kg from the adsorption test. On the South Field sample, the desorption test showed a K_d value of 280.0 L/kg and the adsorption test showed a K_d value of 12.0 L/kg.

The results between the adsorption and desorption tests were different and can be attributed to the difference in the tests. One difference was the generation or presence of uranium in the leachate. In the adsorption test, uranium was added to the leachate at the beginning of the test. In the desorption test, the uranium was leached, during the test, from the soil sample in the leachate.

The uranium in the leachate was also different between the tests. In the adsorption test, the uranium was in the form of uranium nitrate. In the desorption test, the uranium varied chemically depending on the source and/or chemical changes that may have occurred during its presence in the soil. In addition, the desorption test was different than the adsorption test by the process. The desorption test

TABLE D.3-4

SUMMARY OF K_d VALUES FOR OPERABLE UNIT 2

Sample Location	Desorption Test K_d (L/Kg)	Adsorption Test K_d (L/Kg)
Solid Waste Landfill - Waste Material	75.0/88.0	
Solid Waste Landfill - Glacial Overburden	200.0/1370.0	81.0
Inactive Flyash Pile - Cover Material	70.0	
Inactive Flyash Pile/Active Flyash Pile - Flyash		37.0/10,230.0
Lime Sludge Pond - Berm Material	360.0	
Lime Sludge Pond - Lime Sludge	2650.0	
South Field - Waste Material	180.0/280	12.0
South Field - Glacial Overburden	9350.0	
South Field/Solid Waste Landfill - Unsaturated Sand and Gravel		12.0/14.0
South Field/Solid Waste Landfill - Saturated Sand and Gravel		8.0/10.0

worked on the process of removing absorbed uranium from the soil. The adsorption test used the process of soil particles absorbing uranium from solution.

The desorption test is considered more representative for the fill and till layers of the subunits, because it depicts the behavior of the uranium migration in the contaminated soil layers upon contact with infiltration and perched groundwater. Whereas the adsorption test better depicts the sand and gravel layers since, in these layers, the media is free of uranium contamination and would act in an adsorption fashion on contaminated groundwater moving through the media. The adsorption values were mainly used in the unsaturated and saturated sand and gravel zones where the desorption test was not practical, because the soils were not contaminated or not contaminated to a level that would leach at detectable concentrations.

D.3.4.2 Operable Unit 2 K_d Values Versus Literature Values

Several literature reviews were performed to evaluate the range of K_d values for uranium. One reference (Thibault et al. 1990) provided a range of K_d values from 46 to 395,100 L/kg for clay-rich soils and 0.03 to 2,200 L/kg for sandy soils. For agriculture soils or the soil layer where plants and roots uptake nutrients, the K_d value for uranium ranged from 10.5 to 4,400 L/kg (Baes et al. 1984).

Both the waste layer and glacial overburden layer soils at the Solid Waste Landfill and South Field were clay-rich soil with K_d values from 12 to 180 L/Kg for the waste layer and 9,350 L/kg for the glacial overburden layer. In comparison with the literature values, the Operable Unit 2 K_d values were on the low end of the range. Likewise, for the sand and gravel at the Solid Waste Landfill and South Field, the K_d values ranged from 8.0 to 14.0 L/kg, which was on the low end of the literature values for sandy soils. No literature values were obtained for the flyash and lime sludge.

D.3.4.3 Operable Unit 2 K_d Values Versus In Situ Values

A final assessment of the Operable Unit 2 K_d values was made by comparison with in situ samples. The in situ K_d determination was conducted by Operable Unit 5 and was determined by analyzing a soil and water sample at the same location in 1000-series wells. Because the perched water flow velocities are low in the glacial overburden, it was assumed the measured soil and liquid phase concentrations were in equilibrium.

Before the in situ K_ds were calculated, the soil concentration was corrected for the uranium contained in the soil moisture. Approximately 25 percent of the soil uranium concentration was subtracted to adjust for the soil moisture. The Operable Unit 5 in situ K_d values ranged from 16 to 235 L/kg, which were similar to the range of Operable Unit 2 K_d values for the Solid Waste Landfill and South Field in the glacial overburden (12 to 280 L/kg) when the high K_d values are deleted from the Solid Waste Landfill (1,370 L/kg) and South Field (9,350 L/kg).

The Operable Unit 2 RI sampling program collected a soil (silty sand) and water sample from Inactive Flyash Pile Boring No. 11003 at 7.9 m (26 ft), which produced an in situ K_d value of 525 L/kg. Also, a K_d value was calculated for the South Field saturated sand and gravel layer by removing the free liquid from the sample and analyzing the free liquid and sand and gravel material. The sand and gravel were considered to be in equilibrium with the groundwater. A K_d value of 64 L/kg resulted. These two Operable Unit 2 in situ K_d values were much higher then the Operable Unit 2 laboratory K_d values for the sand and gravel layer. The in situ K_d at Boring No. 11003 was believed to be high due to the uranium contamination not being soluble and was probably specific to that area of contamination.

APPENDIX D.3

ATTACHMENT D.3-I

LABORATORY PROCEDURES

ATTACHMENT D.3-1
LABORATORY PROCEDURES

D.3-I.1 Procedure A (Contaminated Samples for Uranium K_d Determination)

D.3-I.1.1 Sample Homogenization

The sample will be thoroughly homogenized using a stainless steel mixing spoon in a stainless steel mixing bowl.

D.3-I.1.2 Sample Filtration

If the sample has any free liquid, it should be vacuum filtered through a .45 micron filter paper. (Note that it may be necessary to use several filtration steps.) Any filtrate should be collected and analyzed for total uranium.

D.3-I.1.3 Initial Characterization of Soil Sample

Samples for the total uranium soil analysis should be split between the FEMP laboratory and the off-site laboratory if adequate sample is available. If there is inadequate sample for the off-site analysis, then samples should only be analyzed at the FEMP laboratory. Sample volumes should be collected for total uranium and placed in the containers as shown in Table D.3-I-1. Additionally, a 10-gram sample should be analyzed for moisture content at the FEMP laboratory.

D.3-I.1.4 Sample Preparation

Place 400 grams (dry weight) of soil sample in the 4.0 liter reactor and add 3,500 ml of the appropriate leachate solution to the reactor. For soil samples collected in the subunits, the leachate solution will be 3,500 ml of deionized (DI) water adjusted to a pH of 5.6 using a mixture of sulfuric acid and nitric acid at a 60/40 ratio. For soil samples collected from the glacial overburden below the subunits, use DI water with no pH adjustment. For soil samples from the sand and gravel zone (unsaturated or saturated) below the subunits, the leachate solution will be clean groundwater from a background well. A sample of the background groundwater must be submitted for total uranium analysis to the off-site laboratory and the FEMP laboratory according to the volumes and container requirements shown in Table D.3-I-1. This analysis will serve as a background concentration for the groundwater used for the testing. (Note: Background groundwater only requires one analysis to establish a baseline concentration.)

D.3-I.1.5 Sample Mixing

The samples should be placed in the rotating tumbler and mixed continuously until completion of the testing. The extractor must be operated at 29 +/- 2 rpm.

D.3-I.1.6 Sample Collection

Samples of the leachate should be collected by stopping the tumbler for a sufficient time period (minimum of 10 minutes) to allow the solids to settle. An appropriate volume of the leachate (see Table D.3-I-1 for sample volumes required for analysis) should then be decanted from the reactor and filtered through a .45 micron filter paper or separated with a constant temperature centrifuge capable of separating greater than 0.1 micron particles. Any solids from the separation step should be returned to the reactor.

Intermediate samples should be collected at 72, 144, 168, 240, 288, 360, and 384 hours and analyzed at the FEMP laboratory for total uranium. The study may be stopped earlier if the data indicates that uranium is in equilibrium with the soil and liquid. Equilibrium will be determined by plotting each concentration (Y-axis) versus time (X-axis) to determine when the curve begins to flatten, which indicates that an equilibrium concentration is achieved. Prior to stopping the test earlier or collecting intermediate samples for one of the radionuclides, confirm with the Operable Unit 2 representative that the contaminant is in equilibrium.

The final sample will be collected after the results indicate that uranium is in equilibrium and will be split between the FEMP laboratory and the off-site laboratory. The final sample will be collected and analyzed for total uranium. If a sample does not reach equilibrium after 384 hours, then the Operable Unit 2 representative (Bert Crapse at extension 6974) should be notified to determine the appropriate action to be taken. (Note: The final water samples should only be split with the FEMP and off-site laboratories if the soil samples were initially split between the two laboratories.)

At the completion of the study, the soil will be stored for possible future leaching tests to determine the extractable concentrations of the radionuclides. Prior to storing the sample, the sample will be vacuum filtered through a .45 micron filter paper to remove all free liquid. The Operable Unit 2 representative will identify which samples will be used to determine the extractable portion.

D.3-I.2 Procedure A1 (Non-Contaminated Samples for Uranium K_d Determination)

D.3-I.2.1 Sample Homogenization

The sample will be thoroughly homogenized using a stainless steel mixing spoon in a stainless steel mixing bowl.

D.3-I.2.2 Sample Filtration

If the sample has any free liquid, it should be vacuum filtered through a .45 micron filter paper. (Note that it may be necessary to use several filtration steps.)

D.3-I.2.3 Initial Characterization of Soil Sample

Samples for the total uranium soil analysis should be split between the FEMP laboratory and the off-site laboratory if an adequate sample is available. If there is inadequate sample for the off-site analysis, then samples should only be analyzed at the FEMP laboratory. Sample volumes should be collected for total uranium and placed in the containers as shown in Table D.3-I-1. Additionally, a 10-gram sample should be analyzed for moisture content at the FEMP laboratory.

D.3-I.2.4 Sample Preparation

Place 400 grams (dry weight) of soil sample in the 4.0 liter reactor and add 3,500 ml of the appropriate leachate solution to the reactor. For soil samples collected in the subunits, the leachate solution will be 3,500 ml of DI water adjusted to a pH of 5.6 using a mixture of sulfuric acid and nitric acid at a 60/40 ratio. For soil samples from the sand and gravel zone (unsaturated or saturated) below the subunits, the leachate solution will be clean groundwater from a background well. If baseline concentration is not established for groundwater, then a sample must be submitted for total uranium analysis to the off-site laboratory and the FEMP laboratory according to the volumes and container requirements shown in Table D.3-I-1.

Once the proper leaching solution has been prepared, the proper mass of radionuclides must be added to obtain a liquid concentration of approximately 100 times the MCL concentration. The following is the MCL (proposed) for uranium:

Radionuclide	MCL	Mass of Radionuclide to be Spiked
Uranium	20 μg/L	7.0 mg Uranium 238

Place 400 grams (dry weight) of soil/waste in the 4.0 liter reactor, and add 3,500 ml of the appropriate leachate solution to the reactor.

D.3-I.2.5 Sample Mixing

The samples should be placed in the rotating tumbler and mixed continuously until completion of the testing. The extractor must be operated at 29 +/- 2 rpm.

D.3-I.2.6 Sample Collection

Samples of the leachate should be collected by stopping the tumbler for a sufficient time period (minimum of 10 minutes) to allow the solids to settle. An appropriate volume of the leachate (see Table D.3-I-1 for sample volumes required for analysis) should then be decanted from the reactor and filtered through a .45 micron filter paper or separated with a constant temperature centrifuge capable of separating greater than 0.1 micron particles. Any solids from the separation step should be returned to the reactor.

Intermediate samples should be collected at 4, 24, 48, and 72 hours. After the 72 hour data point is obtained, verify that the uranium is at an equilibrium concentration between the soil and the leachate solution. Equilibrium will be determined by plotting each concentration (Y-axis) versus time (X-axis) to determine when the curve begins to flatten, which indicates that an equilibrium concentration is achieved. If a sample does not reach equilibrium after 72 hours, then the Operable Unit 2 representative contact person (Bert Crapse at extension 6974) should be notified to determine the appropriate action to be taken.

All of the intermediate samples will be analyzed for total uranium at the FEMP laboratory. The final sample will be collected after the results indicate that uranium is in equilibrium. The final sample will be split between the FEMP laboratory and the off-site laboratory and analyzed for total uranium. (Note: The final water samples should only be split with the FEMP and off-site laboratories if the soil samples were split.)

Table D.3-I-1

SAMPLE VOLUMES/DETECTION LIMIT

Chemical	Media	Method	Volume	Sample Container	Instrument	Detection Limit
Off-Site Laboratory						
Total - Uranium	Water Soil	OR 7127 OR 7003	210 ml 135 g (dry)	250 ml glass 250 ml glass	Laser Phosphorimetry Gamma Spectrometry	1 μg/l 1 ppm
FEMP laboratory						
Total - Uranium	Water Soil	3062 3002	10 ml 5 g	-[a]	Laser Phosphorimetry Color Metric	1 μg/l 0.1 ppm

[a]To be determined by laboratory personnel.

Note: Water samples to be preserved with HNO_3.

APPENDIX D.3

ATTACHMENT D.3-II

LABORATORY RESULTS FOR DESORPTION TESTS

DESORPTION TEST FOR
SOLID WASTE LANDFILL BORING 1986
WASTE MATERIAL
SAMPLE #111455

	SAMPLING PERIOD (DAYS)									
LEACHATE ANALYTICAL PARAMETERS	Start 6/18/93	3	6	7	10	12	14	18	20	28 Final[1]
Total-U Conc. (μg/l)	N/A	1300	1685	1667	1762	1626	1619	1300	1500	1768/ 1700
Percent Concentration Change	-	-	+29.6	-1.1	+5.7	-7.7	-0.4	-19.7	+15.4	+17.9
Ratio Change of Liquid	8.75	8.70	8.65	8.60	8.55	8.50	8.45	8.40	8.35	-
pH	5.60	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Specific Conductivity (μMHOS)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Temp. (°C)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Initial Soil Uranium Concentration = 146 ppm (IT) & 94 ppm (FEMP)
Soil Sample Wt. = 400 g
Initial Liquid to Soil Ratio = 8.75
[1] - final sample split and analyzed for total-U by FEMP/IT Oak Ridge
N/A - Not Analyzed

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DESORPTION TEST FOR
SOLID WASTE LANDFILL BORING 1985
WASTE MATERIAL
SAMPLE #111440

	SAMPLING PERIOD (DAYS)									
LEACHATE ANALYTICAL PARAMETERS	Start 7/19/93	1	3	4	7	10	11	15	17	18 Final[1]
Total-U Conc. (μg/l)	N/A	360	579	465	476	489	507	555	549	551/52.5
Percent Concentration Change	-	-	+61	-19.7	+2.4	+2.7	+3.7	+9.5	-1.1	0.4
Ratio Change of Liquid	8.75	8.70	8.65	8.60	8.55	8.50	8.45	8.40	8.35	-
pH	5.60	8.54	8.42	8.42	8.32	8.04	7.98	7.89	7.85	N/A
Specific Conductivity (μMHOS)	N/A	185	220	234	275	300	310	325	322	N/A
Temp. (°C)	N/A	30.1	31.2	32.0	33.0	32.1	32.0	30.5	28.8	N/A

Initial Soil Uranium Concentration = 74 ppm (IT) & 64 ppm (FEMP)
Moisture Content = 86.5% solid
Soil Wt. = 400g
Initial Liquid to Soil Ratio = 8.75
[1] - final sample split and analyzed for total-U by FEMP/IT Oak Ridge
N/A - Not analyzed

FEMP-OU02-6 FINAL
March 1, 1995

DESORPTION TEST FOR
SOLID WASTE LANDFILL BORING 1986
GLACIAL OVERBURDEN LAYER
SAMPLE #111457

	SAMPLING PERIOD (DAYS)								
LEACHATE ANALYTICAL PARAMETERS	Start 7/27/93	1	3	6	8	10	13	15	16 Final[1]
Total-U Conc. (μg/l)	N/A	6.6	12.1	9.9	9.9	14.0	10.1	14.5	11.6/10.6
Percent Concentration Change	-	-	+83.3	-18.2	0.0	+41.4	-27.9	43.6	-20
Ratio Change of Liquid	8.75	8.70	8.65	8.60	8.55	8.50	8.45	8.40	-
pH	5.60	7.32	7.36	7.23	7.31	7.34	7.26	7.32	7.31
Specific Conductivity (μMHOS)	N/A	170	205	230	248	249	260	265	265
Temp. (°C)	N/A	32.4	30.8	29.6	31.1	28.4	29.4	29.0	28.7

Initial Soil Uranium Concentration = 18.3 ppm (IT) & 6 ppm (FEMP)
Soil Sample Wt. = 400g
Liquid to Soil Ratio = 8.75
Moisture Content = 74.9% solid
[1] - final sample split and analyzed for total-U by FEMP/IT Oak Ridge
N/A - Not analyzed

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DESORPTION TEST FOR
SOLID WASTE LANDFILL BORING 11037
GLACIAL OVERBURDEN LAYER
SAMPLE #115370

LEACHATE ANALYTICAL PARAMETERS	SAMPLING PERIOD (DAYS)								
	Start 7/27/93	1	3	6	8	10	13	15	16 Final[1]
Total-U Conc. (μg/l)	N/A	5.4	10.0	8.6	13.6	7.5	10.8	11.5	10.1/10.0
Percent Concentration Change	-	-	+85.2	-14.0	+58.1	-44.8	+44.0	+6.5	-12.2
Ratio Change of Liquid									
pH	5.60	7.94	7.82	7.80	7.72	7.80	7.76	7.69	7.75
Specific Conductivity (μMHOS)	N/A	300	380	420	430	440	455	467	470
Temp. (°C)	N/A	32.9	31.9	31.3	30.9	28.2	29.0	29.3	28.6

Initial Soil Uranium Concentration = 2.65 ppm (IT) & 9 ppm (FEMP)
Soil sample Wt. = 400g
Liquid to Soil Ratio = 8.75
Moisture Content = 80.9% solid
[1] - final sample split and analyzed for total-U by FEMP/IT Oak Ridge
N/A = Not Analyzed

FEMP-OU02-6 FINAL
March 1, 1995

DESORPTION TEST FOR
LIME SLUDGE PONDS SURFACE SOIL #03
LIME SLUDGE
SAMPLE #114472

	SAMPLING PERIOD (DAYS)								
Analytical Parameters	Start	1	3	6	8	10	13	15	16 Final[1]
Total-U Conc. (μg/l)	0	18.1	34.0	24.9	30.0	31.1	36.1	37.9	40.0/41.6
Percent Concentration Change	-	-	87.8	-26.8	20.5	3.7	16.1	5.0	5.5
Ratio Change of Liquid	8.75	8.70	8.65	8.60	8.55	8.50	8.45	8.40	-
pH	5.60	7.60	7.47	7.28	7.17	7.16	7.08	7.00	7.05
Specific Conductivity (μMHOS)	0	191	257	320	357	380	420	449	455
Temp. (°C)	N/A	33.0	31.7	30.4	31.0	28.6	29.1	29.1	28.8

Initial Soil Uranium Concentration = 18.9 ppm (IT) & 17 ppm (FEMP)
Soil Sample Wt. = 400g
Liquid to Soil Ratio = 8.75
Moisture Content = 80.6% solid
[1] - final sample split and analyzed for total-U by FEMP/IT Oak Ridge
N/A - Not analyzed

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DESORPTION TEST FOR
INACTIVE FLYASH PILE BORING 11001
COVER MATERIAL LAYER (FLYASH)
SAMPLE #114067

LEACHATE ANALYTICAL PARAMETERS	SAMPLING PERIOD (DAYS)									
	Start 7/19/93	1	3	4	7	10	11	15	17	18 Final [1]
Total-U Conc. (μg/l)	N/A	1557	2240	2111	1634	1505	1506	1472	1470	1696/ 1810
Percent Concentration Change	-	-	+43.9	-5.8	-22.6	-7.9	+0.1	-2.3	+0.1	+15.4
Ratio Change of Liquid	8.75	8.70	8.65	8.60	8.55	8.50	8.45	8.40	8.35	-
pH	5.60	8.50	8.47	8.52	8.44	8.27	8.15	8.18	8.20	N/A
Specific Conductivity (μMHOS)	N/A	175	200	213	239	249	264	255	252	N/A
Temp. (°C)	N/A	30.1	31.2	32.2	33.6	31.9	32.2	30.9	28.8	N/A

Initial Soil Uranium Concentration = 147 ppm (IT) & 150 ppm (FEMP)
Soil Sample Wt. = 400g
Liquid to Soil Ratio = 8.75
Moisture Content = 97.9% solid (air-dried)
[1] - Final sample split and analyzed for total-U by FEMP/IT Oak Ridge
N/A - Not analyzed

DESORPTION TEST FOR
INACTIVE FLYASH PILE BORING 11003
WASTE MATERIAL (FLYASH)
SAMPLE #114068

LEACHATE ANALYTICAL PARAMETERS	SAMPLING PERIOD (DAYS)					
	Start 7/29/93	1	3	6	8	10 Final[1]
Total-U Conc. (μg/l)	N/A	<0.2	0.7	<0.2	<0.2	0.5
Percent Concentration Change	-	-	-	-	-	-
Ratio Change of Liquid	8.75	8.70	8.65	8.60	8.55	8.50
pH	5.60	5.95	6.02	5.96	5.95	6.00
Specific Conductivity (μMHOS)	N/A	123	160	178	184	190
Temp. (°C)	N/A	32.5	32.1	29.9	30.9	28.7

Initial Soil Uranium Concentration = 16.9 ppm (IT) & 6 ppm (FEMP)
Soil Sample Wt. = 400g
Liquid to Soil Ratio = 8.75
Moisture Content = 98.8% (air-dried)
N/A - Not Analyzed
Note: Test was stopped due to leachate being below detection limit

DESORPTION TEST FOR
SOUTH FIELD BORING 1974
GLACIAL OVERBURDEN
SAMPLE # 114070

LEACHATE ANALYTICAL PARAMETERS	SAMPLING PERIOD (DAYS)								
	Start 7/27/93	1	3	6	8	10	13	15	16 Final[1]
Total-U Conc. (μg/l)	N/A	15.3	13.6	15.5	32.0	14.7	13.3	18.3	28.0/32.5
Percent Concentration Change	-	-	-11.1	+14.0	+106.5	-54.1	-9.5	+37.6	+53.0
Ratio Change of Liquid	8.75	8.70	8.65	8.60	8.55	8.50	8.45	8.40	-
pH	5.60	7.11	7.28	7.26	7.31	7.29	7.30	7.30	7.41
Specific Conductivity (μMHOS)	N/A	53	60	60	60	60	60	60	65
Temp. (°C)	N/A	33.2	31.1	30.7	30.6	28.7	29.1	28.7	28.8

Initial Soil Uranium Concentration = 308 ppm (IT) & 140 ppm (FEMP)
Soil Sample Wt. = 400g
Liquid to Soil Ratio = 8.75
Moisture Content = 83.3%
[1] - final sample split and analyzed for total-U by FEMP/IT Oak Ridge
N/A - Not analyzed

DESORPTION TEST FOR SOUTH FIELD TRENCH #1 WASTE MATERIAL SAMPLE # 113717

LEACHATE ANALYTICAL PARAMETERS	SAMPLING PERIOD (DAYS)									
	Start 7/19/93	1	3	4	7	10	11	15	17	18 Final[1]
Total-U Conc. (μg/l)	N/A	1621	1831	1314	946	865	1168	1221	1253	1526/ 1480
Percent Concentration Change	-	-	+13.0	-28.2	28.0	-8.6	+35.0	+4.5	+2.6	+21.8
Ratio Change in Liquid	8.75	8.70	8.65	8.60	8.55	8.50	8.45	8.40	8.35	-
pH	5.60	8.85	8.86	8.90	8.90	8.67	8.60	8.47	8.45	N/A
Specific Conductivity (μMHOS)	N/A	170	185	183	211	239	245	260	260	N/A
Temp. (°C)	N/A	30.3	31.3	31.7	33.6	32.2	32.6	31.1	28.9	N/A

Initial Soil Uranium Concentration = 278 ppm (IT) & 96 ppm (FEMP)
Soil Sample Wt. = 400g
Liquid to Soil Ratio = 8.75
Moisture Content = 88.7%
[1] - final sample split and analyzed for total-U by FEMP/IT Oak Ridge
N/A - Not analyzed

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DESORPTION TEST FOR
SOUTH FIELD TRENCH #4
GLACIAL OVERBURDEN LAYER
SAMPLE #113721

LEACHATE ANALYTICAL PARAMETERS	SAMPLING PERIOD (DAYS)									
	Start 7/19/93	1	3	4	7	10	11	15	17	18 Final[1]
Total-U Conc. (μg/l)	N/A	30.1	7.3	2.6	8.0	14.0	10.6	12.1	5.6	2.4/2.16
Percent Concentration Change	-	-	-75.7	-64.4	+207.7	+75.0	-24.3	14.2	-53.7	-57.1
Ratio Change of Liquid	8.75	8.70	8.65	8.60	8.55	8.50	8.45	8.40	8.35	-
pH	5.60	8.44	8.42	8.63	8.60	8.29	8.15	8.10	8.09	N/A
Specific Conductivity (μMHOS)	N/A	103	120	130	143	157	159	165	163	N/A
Temp. (°C)	N/A	30.4	31.4	31.7	33.0	32.3	32.1	30.5	29.0	N/A

Initial Soil Uranium Concentration = 4.34 ppm (IT) & 15 ppm (FEMP)
Soil Sample Wt. = 400g
Liquid to Soil Ratio = 8.75
Moisture Content = 79.7%
[1] - final sample split and analyzed for total-U by FEMP/IT Oak Ridge
N/A - Not analyzed

DESORPTION TEST FOR
LIME SLUDGE POND SURFACE SOIL #05/06
LIME SLUDGE
SAMPLE #114494

LEACHATE ANALYTICAL PARAMETERS	SAMPLING PERIOD (DAYS)										
	Start 8/19/93	1	4	6	8	11	12	13	14	15	19 Final[1]
Total-U Conc. (μg/l)	N/A	8.2	5.4	5.7	276^	3934^	39	48	1.8	3.8	6.4
Percent Concentration Change	-	-	-34.1	+3.7	>1000	>1000	-99	+23.0	-96.3	+111	+40.6
Ratio Change of Liquid	8.75	8.70	8.65	8.60	8.55	8.50	8.45	8.40	8.35	8.30	-
pH	8.90	8.81	8.77	8.84	8.86	8.81	8.85	8.74	8.75	8.74	8.70
Specific Conductivity (μMHOS)	152	202	216	218	232	239	240	238	236	247	270
Temp. (°C)	23.8	25.3	24.9	23.7	25.8	25.1	25.4	24	22.6	25.1	24.6

Initial Soil Uranium Concentration = ? ppm (IT) & 15 ppm (FEMP)
Moisture Content = 56.66% solid
Soil Sample Wt. = 400g
Liquid to Soil Ratio = 8.75
[1] - final sample split and analyzed for total-U by FEMP/IT Oak Ridge
^ - samples were contaminated
N/A - Not Analyzed

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APPENDIX D.3

ATTACHMENT D.3-III

LABORATORY RESULTS FOR ADSORPTION TESTS

ADSORPTION TEST FOR
SOLID WASTE LANDFILL BORING 2953
UNSATURATED SAND AND GRAVEL LAYER
SAMPLE # 115445

	SAMPLING PERIOD (DAYS)											
LEACHATE ANALYTICAL PARAMETERS	Start 7/20/93	1/6 (4 hr)	1	2	3	6	8	9	13	15	16	17 Final[1]
Total-U Conc. (μg/l)	2000	1697	1354	1262	1492	1361	897	948	839	736	888	793/918
Percent Concentration Change	-	+15.2	+20.2	+6.8	-18.2	+8.8	+34.1	-5.7	+11.5	+12.3	-20.7	+10.7
Ratio Change of Liquid	8.75	8.7	8.65	8.6	8.55	8.50	8.45	8.40	8.35	8.30	8.25	-
pH	6.70	6.95	6.82	6.86	7.00	7.03	7.07	7.20	7.27	7.29	7.35	N/A
Specific Conductivity (μMHOS)	700	1480	1470	1470	1470	1500	1440	1420	1400	1380	1340	N/A
Temp. (°C)	N/A	28.8	30.2	30.0	31.2	33.1	31.0	32.3	30.6	30.5	28.2	N/A

Initial Soil Uranium Concentration = 1.63 ppm (IT) & 4 ppm (FEMP)
Soil Sample Wt. = 400g
Liquid to Soil Ratio = 8.75
Moisture Content = 96.8% solids
[1] - final sample split and analyzed for total-U by FEMP/IT Oak Ridge
N/A - Not analyzed

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ADSORPTION TEST FOR
SOLID WASTE LANDFILL BORING 2953
SATURATED SAND AND GRAVEL LAYER
SAMPLE # 115454

LEACHATE ANALYTICAL PARAMETERS	SAMPLING PERIOD (DAYS)											
	Start 7/20/93	1/6 (4 hr.)	1	2	3	6	8	9	13	15	16	17 Final[1]
Total-U Conc. (μg/l)	2000	1258	1282	1247	1240	1172	969	1035	873	851	900	752/982
Percent Concentration Change	-	+37.1	-1.9	+2.7	+0.6	+5.5	+17.3	-6.8	+15.6	+2.5	-5.8	+16.4
Ratio Change in Liquid	8.75	8.70	8.65	8.60	8.55	8.50	8.45	8.40	8.35	8.30	8.25	
pH	6.70	7.12	7.09	7.11	7.30	7.25	7.20	7.40	7.45	7.45	7.52	N/A
Specific Conductivity (μMHOS)	700	900	900	900	920	980	920	900	920	900	880	N/A
Temp. (°C)	N/A	28.6	30.2	30.3	31.5	33.1	31.1	31.1	30.6	30.5	28.1	N/A

Initial Soil Uranium Concentration = 1.17 ppm (IT) & 4 ppm (FEMP)
Soil Sample Wt. = 400g
Liquid to Soil Ratio = 8.75
Moisture Content = 86.3% solid
[1] - final sample split and analyzed for total-U by FEMP/IT Oak Ridge
N/A - Not analyzed

ADSORPTION TEST FOR
SOLID WASTE LANDFILL BORING 1986
GLACIAL OVERBURDEN LAYER
SAMPLE # 111457

LEACHATE ANALYTICAL PARAMETERS	SAMPLING PERIOD (DAYS)								
	Start 7/27/93	1/6 (4 hr)	1	2	3	7	8	10	10 Final[1]
Total-U Conc. (μg/l)	2000	506	334	367	343	295	283	288	318/357
Percent Concentration Change	-	+74.7	+34.0	-9.9	+6.5	+14.0	+4.1	-1.8	-10.4
Ratio Change in Liquid	8.75	8.70	8.65	8.6	8.55	8.5	8.45	8.4	-
pH	6.70	7.49	6.84	6.92	6.99	6.95	6.96	7.13	N/A
Specific Conductivity (μMHOS)	700	830	810	810	800	790	780	750	N/A
Temp. (°C)	N/A	32.1	32.7	31.8	32.0	30.1	30.8	28.3	N/A

Initial Soil Uranium Concentration = 18.3 ppm (IT) & 6 ppm (FEMP)
Soil Sample Wt. = 400g
Liquid to Soil Ratio = 8.75
Moisture Content = 74.9% solid
[1] - final sample split and analyzed for total-U by FEMP/IT Oak Ridge
N/A - Not analyzed

000041

2386

ADSORPTION TEST FOR
ACTIVE FLYASH PILE BORING 1980
WASTE MATERIAL (FLYASH)
SAMPLE # 114069

LEACHATE ANALYTICAL PARAMETERS	SAMPLING PERIOD (DAYS)									
	Start 7/20/93	1/6 (4 hr.)	1	2	3	6	8	9	10	10 Final[1]
Total-U Conc. (μg/l)	2000	668	612	564	556	450	431	507	449	493/564
Percent Concentration Change	-	+66.6	+8.4	+7.8	+1.4	+19.1	+4.2	-17.6	+11.4	-9.8
Ratio Change in Liquid	8.75	8.7	8.65	8.6	8.55	8.50	8.45	8.4	8.35	-
pH	6.70	6.81	6.85	6.86	6.95	6.90	6.80	6.96	7.00	N/A
Specific Conductivity (μMHOS)	700	1380	1400	1400	1400	1450	1400	1400	1280	N/A
Temp. (°C)	N/A	28.4	28.9	30.3	30.9	32.5	31.4	30.6	27.9	N/A

Initial Soil Uranium Concentration = 12.2 ppm(IT) & 6 ppm (FEMP)
Moisture Content = 99.3% solid (air-dried)
Soil Sample Wt. = 400g
Liquid to Soil Ratio = 8.75
[1] - final sample split and analyzed for total-U by FEMP/IT Oak Ridge
N/A - Not analyzed

ADSORPTION TEST FOR
SOUTH FIELD TRENCH #4
GLACIAL OVERBURDEN LAYER
SAMPLE #113721

LEACHATE ANALYTICAL PARAMETERS	SAMPLING PERIOD (DAYS)											
	Start 7/20/93	1/6 (4 hrs.)	1	2	3	6	8	9	13	15	16	17 Final[1]
Total-U Conc. (μg/l)	2000	1072	1282	1122	1015	878	748	854	718	714	785	724/876
Percent Concentration Change	-	+46.4	-19.6	+12.5	+9.5	+13.5	+14.8	-14.2	+15.9	+0.6	-9.9	+7.7
Ratio Change in Liquid	8.75	8.7	8.65	8.6	8.55	8.5	8.45	8.4	8.35	8.3	8.25	-
pH	6.70	7.10	7.14	7.20	7.30	7.21	7.00	7.25	7.26	7.22	7.34	N/A
Specific Conductivity (μMHOS)	700	810	810	820	830	800	780	790	800	780	720	N/A
Temp. (°C)	N/A	28.7	29.1	30.3	31.0	32.4	31.6	30.6	30.4	30.7	27.8	N/A

Initial Soil Uranium Concentration = 1.63 ppm (IT) & 15 ppm (FEMP)
Soil Sample Wt. = 400g
Liquid to Soil Ratio = 8.75
Moisture Content = 79.7%
[1] - final sample split and analyzed for total-U by FEMP/IT Oak Ridge
N/A - Not analyzed

ADSORPTION TEST FOR
SOUTH FIELD BORING 2944
UNSATURATED SAND AND GRAVEL LAYER
SAMPLE #113755

LEACHATE ANALYTICAL PARAMETERS	SAMPLING PERIOD (DAYS)									
	Start 7/20/93	1/6 (4 hrs.)	1	2	3	6	8	9	10	10 Final[1]
Total-U Conc. (μg/l)	2000	1564	1080	1285	1209	898	791	777	609	651/826
Percent Concentration Change	-	+21.8	+30.9	-19.0	+5.9	+25.7	+11.9	+17.7	+21.6	-6.9
Ratio Change in Liquid	8.75	8.7	8.65	8.6	8.55	8.5	8.45	8.4	8.35	-
pH	6.70	7.03	7.14	7.20	7.35	7.37	7.22	7.46	7.50	N/A
Specific Conductivity (μMHOS)	700	850	880	880	890	900	880	850	800	N/A
Temp. (°C)	N/A	28.6	29.7	30.0	31.0	33.0	31.0	32.0	29.8	N/A

Initial Soil Uranium Concentration = 1.43 ppm (IT) & 2 ppm (FEMP)
Soil Sample Wt. = 400g
Liquid to Soil Ratio = 8.75
Moisture Content = 93.1% solid
[1] - final sample split and analyzed for total-U by FEMP/IT Oak Ridge
N/A - Not analyzed

000044

ADSORPTION TEST #1 FOR
SOUTH FIELD BORING 2944
SATURATED SAND AND GRAVEL
SAMPLE #113770

	SAMPLING PERIOD (DAYS)									
LEACHATE ANALYTICAL PARAMETERS	Start 7/20/93	1/6 (4 hours)	1	2	3	6	8	9	10	10 Final[1]
Total-U Conc. (μg/l)	2000	1593	1598	1423	1417	1310	1290	1326	1219	958/1190
Percent Concentration Change	-	+20.4	-0.3	+11.0	+0.4	+7.6	+1.5	-2.8	+8.1	+21.4
Ratio Change in Liquid	8.75	8.7	8.65	8.6	8.55	8.5	8.45	8.4	8.35	-
pH	6.70	7.09	7.21	7.26	7.40	7.36	7.17	7.49	7.50	N/A
Specific Conductivity (uMHOS)	700	850	900	900	900	900	890	840	800	N/A
Temp. (°C)	N/A	28.6	30.0	30.4	30.8	32.5	31.4	31.1	28.4	N/A

Initial Soil Uranium Concentration = 2.86 ppm (IT) & 6 ppm (FEMP)
Soil Sample Wt. = 400g
Liquid to Soil Ratio = 8.75
Moisture Content = 98.8% solid (air-dried)
[1] - final sample split and analyzed for total-U by FEMP/IT Oak Ridge
N/A - Not analyzed

ADSORPTION TEST FOR
INACTIVE FLYASH PILE BORING 11003
WASTE MATERIAL (FLYASH)
SAMPLE #114068

LEACHATE ANALYTICAL PARAMETERS	SAMPLING PERIOD (DAYS)						
	Start 8/11/93	1/6 (4 hours)	1	2	5	6	7 Final[1]
Total-U Conc. (μg/l)	2000	3.2	4.0	1.2	4.0	2.6	3.1/ <1.0
Percent Concentration Change	-	+99.8	-25.0	+70.0	-233.3	+35.0	-19.2
Ratio Change to LIquid	8.75	8.70	8.65	8.60	8.55	8.50	-
pH	N/A	5.71	5.76	5.79	5.81	5.83	5.79
Specific Conductivity (μMHOS)	N/A	287	286	255	260	268	269
Temp. (°C)	N/A	29.9	29.5	23.3	24.3	25.0	25.1

Initial Soil Uranium Concentration = 16.9 ppm (IT) & 6 ppm (FEMP)
Moisture Content = 98.8% solid (air-dried)
Soil Sample Wt. = 400g
Liquid to Soil Ratio = 8.75
[1] - final sample split and analyzed for total-U by FEMP/IT Oak Ridge
N/A - Not analyzed

000046

APPENDIX D.3

ATTACHMENT D.3-IV

K_d CALCULATIONS FOR DESORPTION TESTS

Desorption Test Calculations

10/15/93
B. Crapse

Symbols and Units

$$K_d = \frac{C_s'}{C_L}$$

V = volume of liquid used during equilibrium tests always ≈ 3.5 liters

M = mass of soil or test media; ≈ 400 grams

C_o = initial concentration of uranium in soil or test media (μg/g)

C_s = concentration of uranium in soil or test media at equilibrium (μg/g)

C_b = background concentration of uranium in soil; calculated ≈ 3.7 μg/g

C_L = concentration of uranium in liquid at equilibrium (μg/l)

C_s' = final concentration of uranium in soil or test media above background (μg/g)

m_L = mass of uranium leached from soil (μg)

m_s = mass of uranium in soil at equilibrium (μg)

---

① Sample # 111457 (Glacial Overburden)

C_o = 18.3 μg/g

C_L = 10.6 μg/l

uranium mass leached from soil

$$m_L = C_L V = (10.6\ \mu g/l)(3.5\ l) = 37.1\ \mu g$$

uranium mass remaining in soil

$$m_s = C_o M - 37.1\ \mu g = (18.3\ \mu g/g)(400\ g) - 37.1\ \mu g$$

$$= 7282.9\ \mu g$$

$$C_s = \frac{m_s}{M} = \frac{7282.9\ \mu g}{400\ g} = 18.2\ \mu g$$

10/15/9

subtract background concentration from sample

$$C_s' = C_s - C_b = 18.2\ \mu g/g - 3.7\ \mu g/g$$

$$= 14.5\ \mu g/g$$

so, $$K_d = \frac{C_s'}{C_L} = \frac{14.5\ \mu g/g}{10.6\ \mu g/\ell} = 1.37\ \ell/g = 1370\ \ell/kg$$

---

(2) Sample # 111440 (Waste Material)

$C_o = 74.0\ \mu g/g$

$C_L = 726.0\ \mu g/\ell$

uranium mass leached from soil

$$m_\ell = C_L V = (726.0\ \mu g/\ell)(3.5\ \ell)$$

$$= 2541.0\ \mu g$$

uranium mass remaining in soil

$$m_s = C_o M - 2541.0\ \mu g = (74.0\ \mu g/g)(400\ g) - 2541.0\ \mu g$$

$$= 27{,}059\ \mu g$$

$$C_s = \frac{m_s}{M} = \frac{27{,}059\ \mu g}{400\ g} = 67.6\ \mu g/g$$

subtract background concentration from sample

$$C_s' = C_s - C_b = 67.6\ \mu g/g - 3.7\ \mu g/g$$

$$= 63.9\ \mu g/g$$

so, $$K_d = \frac{C_s'}{C_L} = \frac{63.9\ \mu g/g}{726.0\ \mu g/\ell} = 0.088\ \ell/g = 88\ \ell/kg$$

000049

10/15/

Checked by: [illegible]

③ Sample # 111455 (waste material)

$C_o = 146.0\ mg/g$

$C_L = 1700\ mg/l$

$$C_s = \frac{(C_o \times M) - (C_L \times V)}{M} = \frac{[(146.0\ mg/g)(400g) - (1700\ mg/l)(3.5$$

$$= 131.1\ mg/g$$

$$C_s' = 131.1\ mg/g - 3.7\ mg/g = 127.4\ mg/g$$

$$K_d = \frac{C_s'}{C_L} = \frac{127.4\ mg/g}{1700} = 0.075\ l/g = 75\ l/kg$$

---

④ Sample # 115370 (Glacial Overburden)

$$C_o = \frac{9.0\ mg/g + 2.65\ mg/g}{2} = 5.83\ mg/g$$ {average of both IT + FEMP analysis}

$C_L = 10.0\ mg/l$

$$C_s = \frac{(C_o \times M) - (C_L \times V)}{M} = \frac{[(5.83\ mg/g)(400g) - (10.0\ mg/l)(3.5l)]}{400g}$$

$$= 5.7\ mg/g$$

$$C_s' = C_s - C_b = 5.7\ mg/g - 3.7\ mg/g = 2.0\ mg/g$$

$$K_d = \frac{C_s'}{C_L} = \frac{2.0\ mg/g}{10.0\ mg/l} = 0.2\ l/g = 200\ l/kg$$

10/15/93
Checked by: ACL

(5) Sample # 114472 (Waste Material)

$C_o = 18.9\ mg/g$
$C_L = 41.6\ mg/l$

$$C_s = \frac{(C_o \times M) - (C_L \times V)}{M} = \frac{[(18.9\ mg/g)(400g) - (41.6\ mg/l)(3.5l)]}{400g}$$

$$= 18.5\ mg/g$$

$$C_s' = 18.5\ mg/g - 3.7\ mg/g = 14.8\ mg/g$$

$$K_d = \frac{C_s'}{C_L} = \frac{14.8\ mg/g}{41.6\ mg/l} = 0.36\ l/g = 360\ l/kg$$

---

(6) Sample # 114067 (Cover Material)

$C_o = 147.0\ mg/g$
$C_L = 1810.0\ mg/l$

$$C_s = \frac{(147.0\ mg/g)(400g) - (1810.0\ mg/l)(3.5l)}{400g} = 131.2\ mg/g$$

$$C_s' = 131.2\ mg/g - 3.7\ mg/g = 127.5\ mg/g$$

$$K_d = \frac{C_s'}{C_L} = \frac{127.5\ mg/g}{1810\ mg/l} = 0.07\ l/g = 70\ l/kg$$

10/15/93
Checked by: ACS

Desorption Test | Calculations | pg. 5 of 6
10/15/93
B. Crapse

(7) Sample # 114070 (Glacial overburden)

$C_o = 308\ \mu g/g$

$C_L = 32.5\ \mu g/l$

$$C_s = \frac{(308.0\ \mu g/g)(400\ g) - (32.5\ \mu g/l)(3.5\ l)}{400\ g} = 307.7\ \mu g/g$$

$$C_s' = C_s - C_b = 307.7\ \mu g/g - 3.7\ \mu g/g$$

$$= 304\ \mu g/g$$

$$K_d = \frac{C_s'}{C_L} = \frac{304\ \mu g/g}{32.5\ \mu g/l} = 9.35\ l/g = 9350\ l/kg$$

(8) Sample # 113717 (Waste Material)

$C_o = 278.0\ \mu g/g$

$C_L = 1480.0\ \mu g/l$

$$C_s = \frac{(278.0\ \mu g/g)(400\ g) - (1480\ \mu g/l)(3.5\ l)}{400\ g} = 265.1\ \mu g/g$$

$$C_s' = 265.1\ \mu g/g - 3.7\ \mu g/g = 261.4\ \mu g/g$$

$$K_d = \frac{C_s'}{C_L} = \frac{261.4\ \mu g/g}{1480\ \mu g/l} = .18\ l/g = 180\ l/kg$$

000052

10/15/93
checked by: AC

Desorption Test | Calculations | pg. 6 of 6

10-15-93
B. Crapse

(9) Sample # 113721 (Glacial overburden)

$C_o = 4.34\ \mu g/g$

$C_L = 2.16\ \mu g/\ell$

$$C_s = \frac{(4.34\ \mu g/g)(400g) - (2.16\ \mu g/\ell)(3.5\ell)}{400g} = 4.3\ \mu g/g$$

$$C_s' = 4.3\ \mu g/g - 3.7\ \mu g/g = 0.6\ \mu g/g$$

$$K_d = \frac{C_s'}{C_L} = \frac{0.6\ \mu g/g}{2.16\ \mu g/\ell} = .28\ \ell/g = 280\ \ell/kg$$

(10) Sample # 114494 (Lime sludge)

$C_o = 14.3\ \mu g/g$

$C_L = 4.0\ \mu g/\ell$

$$C_s = \frac{(14.3\ \mu g/g)(400g) - (4.0\ \mu g/\ell)(3.5\ell)}{400\ g} = 14.3\ \mu g/g$$

$$C_s' = 14.3\ \mu g/g - 3.7\ \mu g/g = 10.6\ \mu g/g$$

$$K_d = \frac{C_s'}{C_L} = \frac{10.6\ \mu g/g}{4.0\ \mu g/\ell} = 2.65\ \ell/g$$

$$= 2650\ \ell/kg$$

000053

10/15/93
Checked by: ACS

APPENDIX D.3

ATTACHMENT D.3-V

K_d CALCULATIONS FOR ADSORPTION TESTS

FEMP-OU02-6 FINAL
March 1, 1995

10-15-93
B. Crapse

7386

Symbols and units:

V = volume of liquid used during equilibrium test always ≈ 3.5 liters

M = mass of soil or test media; approximately 400 grams

S = initial concentration of uranium in spiked solution ≈ 2000 μg/l

C_o = initial concentration of uranium in soil or test media (μg/g)

C_s = concentration of uranium in soil or test media at equilibrium (μg/g)

C_b = background concentration of uranium in soil; calculated ≈ 3.7 μg/g

C_L = concentration of uranium in liquid at equilibrium (μg/l)

C_s' = final concentration of uranium in soil or test media above background μg/g

C_a = concentration of uranium adsorbed in soil or test media above background (μg/g)

m_a = mass of uranium adsorbed in soil or test media (μg)

$$K_d = \text{adsorption coefficient} \left(\frac{l}{kg}\right) = \frac{C_s'}{C_L}$$

Assumption: The mass of soil prior to the leachate testing is approximately equal to the mass of soil after the leachate testing.

10/18/
Checked by: AC

FEMP-OU02-6 FINAL
March 1, 1995

① Sample # 115445 (Unsaturated sand + gravel)

$C_o = 1.63\ \mu g/g$

$C_L = 918.0\ \mu g/\ell$

mass of uranium adsorbed

$$m_a = SV - C_L V = (2000\ \mu g/\ell)(3.5\ \ell) - (918.0\ \mu g/\ell)(3.5\ \ell)$$

$$= 3787.0\ \mu g$$

Concentration of uranium adsorbed

$$C_a = \frac{m_a}{M} = \frac{3787.0\ \mu g}{400\ g} = 9.5\ \mu g/g$$

Concentration of uranium in soil at equilibrium

$$C_s = C_o + C_a = 1.63\ \mu g/g + 9.5\ \mu g/g = 11.1\ \mu g/g$$

$$C_s' = C_s$$ [background concentration not subtracted]

<u>Note</u>: The background concentration was not subtracted because site groundwater was used for the water solutions. When groundwater is used, the background concentration in the soil is assumed to be in equilibrium with groundwater background concentration.

$$K_d = \frac{C_s'}{C_L} = \frac{11.1\ \mu g/g}{918.0\ \mu g/\ell} = 0.012\ \ell/g$$

$$= 12.0\ \ell/kg$$

000056

checked by: AC 10/18

Adsorption Test | Calculations | pg. 4 of 6

10-15-93
B. Capse

concentration in soil at equilibrium

$C_s = 14.4\ \mu g/g + 18.3\ \mu g/g$

$C_s = 32.7\ \mu g/g$

subtract background concentration for soil

$C_s' = C_s - C_b = 32.7\ \mu g/g - 3.7\ \mu g/g$

$= 29.0\ \mu g/g$

$K_d = \frac{C_s'}{C_L} = \frac{29.0\ \mu g/g}{357.0\ \mu g/L} = 0.081\ L/g$

$K_d = 81\ L/kg$

---

(4) Sample # 113721 (Glacial Overburden)

$C_o = 4.34\ \mu g/g$

$C_L = 876.0\ \mu g/L$

Concentration adsorbed

$C_a = \frac{(2000\ \mu g/L)(3.5L) - (876.0\ \mu g/L)(3.5L)}{400g}$

$= 9.84\ \mu g/g$

concentration at equilibrium

$C_s = 9.84\ \mu g/g + 4.34\ \mu g/g = 14.2\ \mu g/g$

$C_s' = 14.2\ \mu g/g - 3.7\ \mu g/g = 10.4\ \mu g/g$

$K_d = \frac{10.4\ \mu g/g}{876.0\ \mu g/L} = 0.012\ L/g = 12\ L/kg$

10/18
checked by: [illegible]

10-15-97
B. Crapse

7386

(2) Sample # 115454 (Saturated sand + gravel)

$C_o = 1.17\ \mu g/g$

$C_L = 982.0\ \mu g/l$

mass of uranium adsorbed

$$m_a = SV - C_L V = (2000\ \mu g/l)(3.5\ l) - (982.0\ \mu g/l)(3.5\ l)$$

$$= 3563.0\ \mu g$$

Concentration of uranium adsorbed

$$C_a = \frac{m_a}{M} = \frac{3563.0\ \mu g}{400\ g} = 8.9\ \mu g/g$$

Concentration of uranium in soil at equilibrium

$$C_s = C_o + C_a = 1.17\ \mu g/g + 8.9\ \mu g/g = 10.1\ \mu g/g$$

$$C_s' = C_s$$

$$K_d = \frac{C_s'}{C_L} = \frac{10.1\ \mu g/g}{982\ \mu g/l} = 0.010\ l/g$$

$$= 10\ l/kg$$

---

(3) Sample # 111457 (Glacial Overburden)

$C_o = 18.3\ \mu g/g$

$C_L = 357.0\ \mu g/l$

amount of uranium adsorbed

$$m_a = SV - C_L V = (2000\ \mu g/l)(3.5\ l) - (357.0\ \mu g/l)(3.5\ l)$$

$$= 5750.5\ \mu g$$

Concentration adsorbed

$$C_a = \frac{m_a}{M} = \frac{5750.5\ \mu g}{400\ g} = 14.4\ \mu g/g$$

000057

10/15
Checked by: [illegible]

Adsorption Test Calculations

10-15-93
B. Crapse

FEMP-OU02-6 FINAL
March 1, 1995

7386

(5) Sample # 113755 (Unsaturated sand and gravel)

$C_o = 1.43\ \mu g/g$

$C_L = 826.0\ \mu g/l$

concentration adsorbed

$$C_a = \frac{(2000\ \mu g/l)(3.5\ l) - (826\ \mu g/l)(3.5\ l)}{400\ g}$$

$$= 10.3\ \mu g/g$$

concentration at equilibrium

$$C_s = 10.3\ \mu g/g + 1.43\ \mu g/g = 11.7\ \mu g/g$$

$$C_s' = C_s$$

$$K_d = \frac{C_s'}{C_L} = \frac{11.7\ \mu g/g}{826.0\ \mu g/l} = 0.014\ l/g$$

$$= 14\ l/kg$$

(6) Sample # 113770 (Saturated sand + gravel)

$C_o = 2.86\ \mu g/g$

$C_L = 1190\ \mu g/l$

$$C_a = \frac{(2000\ \mu g/l)(3.5\ l) - (1190\ \mu g/l)(3.5\ l)}{400\ g} = 7.088\ \mu g/g$$

$$C_s = 7.09\ \mu g/g + 2.86\ \mu g/g = 9.95\ \mu g/g$$

$$C_s' = C_s$$

$$K_d = \frac{9.95\ \mu g/g}{1190\ \mu g/l} = 0.0084\ l/g$$

$$k_d = \text{[redacted]} = 8.4\ l/kg$$

00059

10/1

Checked by: AC

10-15-93
B. Caplan

(7) Sample # 114068 (Flyash)

$C_o = 16.9\ \mu g/g$

$C_L = 3.0\ \mu g/l$

$$C_a = \frac{(2000\ \mu g/l)(3.5\ l) - (3.0\ \mu g/l)(3.5\ l)}{400\ g} = 17.5\ \mu g/g$$

$$C_s = 17.5\ \mu g/g + 16.9\ \mu g/g = 34.4\ \mu g/g$$

$$C_s' = 34.7\ \mu g/g - 3.7\ \mu g/g = 30.7\ \mu g/g$$

$$K_d = \frac{C_s'}{C_L} = \frac{30.7\ \mu g/g}{3.0\ \mu g/l} = 10.23\ l/g$$

$$K_d = 10{,}230\ l/kg$$

(8) Sample # 114069 (Flyash Material)

$C_o = 12.2\ \mu g/g$

$C_L = 564.0\ \mu g/l$

$$C_a = \frac{(2000\ \mu g/l)(3.5\ l) - (564.0\ \mu g/l)(3.5\ l)}{400\ g} = 12.6$$

$$C_s = 12.6\ \mu g/g + 12.2\ \mu g/g = 24.8\ \mu g/g$$

$$C_s' = 24.8\ \mu g/g - 3.7\ \mu g/g = 21.1\ \mu g/g$$

$$K_d = \frac{C_s'}{C_L} = \frac{21.1\ \mu g/g}{564.0\ \mu g/l} = 0.037\ l/g$$

$$= 37\ l/kg$$

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10/18
Checked by: AC