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PNNL-30717

Round Robin Summary for ASTM Method C1733

November 2020

RM Asmussen
SK Cooley
NM Avalos

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Pacific Northwest National Laboratory
Richland, Washington 99354

Summary

This report was prepared to summarize the results of an inter- and intra-laboratory round robin of ASTM Method C1733-17 (now C1733-20a) *Distribution Coefficients of Inorganic Species by the Batch Method*. The testing used the sorption of cesium (Cs) to a standard reference soil from the San Joaquin Valley (NIST Standard Reference Material 2709a). The data collected from the nine participants was used for a statistical analysis to assess the precision of the method and generate a precision and bias statement to update the C1733-20a standard.

Acknowledgments

The authors would like to thank Elvie Brown and David Swanberg of Washington River Protection Solutions, LLC for providing funding for the purchase of the reference soil. Participants in the round robin were voluntary and not provided with support funding and the authors are grateful for their willingness to contribute. Specifically we thank Claire Tully and James Noel of Western University (London, Ontario, Canada), Kirsten Sockwell and Yelena Katsenovich of Florida International University (Miami, Florida), Daniel Kaplan and Kimberly Roberts of Savannah River National Laboratory (Aiken, South Carolina), Wooyong Um and Hyun Ju of Postech University (Pohang, South Korea), Melissa Mills of Sandia National Laboratories (Albuquerque, New Mexico), William Ebert of Argonne National Laboratory (Lamont, Illinois), Benjamin Parruzot of the Applied Process Engineering Laboratory at Pacific Northwest National Laboratory (PNNL), Michelle Valenta Snyder of the Environmental Sciences Laboratory at PNNL and Emily Campbell of the Radiochemical Processing Laboratory at PNNL for their participation in the round robin. The authors also thank Gary Smith for his review of this report and support as chair of ASTM International Subcommittee C26.13.

Acronyms and Abbreviations

K_d	distribution coefficient
NIST	National Institute of Standards and Technology
PNNL	Pacific Northwest National Laboratory
SRM	standard reference material

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1.0 Introduction

As an aqueous fluid contacts environmental or engineered materials, reactions occur that are dependent upon the chemistries of the fluid itself, other fluids in the system and the solid phases with which it comes in contact. These interactions affect the transport rate of molecules in the migrating fluid. Many processes can influence the transport of the molecules in the migrating fluid including ion exchange, sorption, complex formation, precipitation (or co-precipitation), redox reactions, and precipitate filtration. Partitioning between the solid and liquid phase may be caused by sorption, precipitation, and co-precipitation.

An empirical ratio known as the *distribution coefficient (K_d)* is used to quantify the combined effect of these various processes for the purpose of simulation modeling. K_d is used to describe the extent to which a chemical species will be removed from solution by a solid phase during fluid migration. K_d is commonly defined using Equation (1).

$$K_d = \frac{Mass\ of\ solute\ on\ the\ solid\ phase\ per\ unit\ mass\ of\ solid\ phase}{Mass\ of\ solute\ in\ solution\ per\ unit\ volume\ of\ liquid\ phase} \quad (1)$$

The K_d for a specific molecule is commonly defined as the ratio of the mass sorbed per unit of solid phase to the mass remaining per unit of solution. The usual units of K_d are mL/g.

The common method of determining K_d is the batch method in which concentrations of the chemical species in solid and liquid phases are measured when in contact with one another. Other methods include dynamic column flow-through methods using continuous input of tracer or pulsed input. In field scale studies, a dual tracer test can be conducted using a non-sorbing tracer (e.g., bromide) and compared to the species of interest. The difference in travel times in the system of the two species can be used to calculate K_d.

Measurements for K_d are performed using ASTM Method C1733-20a "*Standard Test Method for Distribution Coefficients of Inorganic Species by the Batch Method*" (ASTM International, 2020). Prior to the most recent update to the standard, no precision and bias statement was available for the standard as a round robin analysis of the method had yet to be performed. This report summarizes the results of a round robin effort to evaluate variability induced from the ASTM C1733-20a method. Note, the round robin was performed when the standard was active as C1733-17. The datasheets delivered to the participant institutions can be seen in Appendix A and Appendix B.

2.0 Round Robin Details

The selected system for evaluating the ASTM C1733-17a (now ASTM C1733-20a) method was the sorption of cesium (Cs) to San Joaquin soil. The San Joaquin soil is National Institute of Standards and Technology (NIST) Standard Reference Material (SRM) #2709a. The Certificate of Analysis for the SRM is given in Appendix C. The experimental system was selected to align with previous scoping work performed at Argonne National Laboratory that identified this system as suitable for a round robin evaluation (Ebert, Petri, 2012). Each participant prepared solutions with varying starting concentrations of Cs using CsCl. The CsCl was purchased from Sigma Aldrich and individual aliquots provided to each participant along with the soil samples. The experimental details provided to each participant are given below.

2.1 Apparatus

1. *Laboratory Ware* (plastic bottles, pipettes) cleaned in a manner consistent with the analyses to be performed and the required precision. Clean, ready to use bottles were supplied for use.

2. *Filters,* filtration apparatus, (syringe filters), capable of removing particles of ≥0.45 micrometers were provided. Filter media selected to limit sorption.

3. *Laboratory Shaker/Rotator/Agitator*

4. *Environmental Monitoring Instruments,* a pH meter and thermometer.

5. *Analytical Balance* capable of measuring to 0.01g.

6. *Analytical Instrumentation,* appropriate for determination of the concentration of major constituents (cations and anions) and of the species of interest (for which K_d is being determined) in the contact solutions (and, optionally, in the solid material samples). In this round robin the analyte of interest is Cesium.

2.2 Sampling

1. The solid samples of soil used were a NIST Reference San Joaquin Soil (2709a).

2. The sample origin is known

3. Geological description of the soil is available through NIST.

4. Ground water is not used in this round robin exercise, but a consistent test duration was used across participating groups to ensure species leached from soil are equivalent.

2.3 Procedure

2.3.1 Solution Preparation

1. Due to the quantities of the standard reference soil available, ASTM Type I (> 18 MΩ·cm, based on ASTM D1193-06(2018) *Standard Specifications for Reagent Water*) water was suggested to

be used to fabricate the cesium-containing solution and not a soil equilibrated solution. If water not meeting ASTM Type I designation was not available, participants were requested to document the water source used.

2. Three solutions of differing Cs concentration were prepared and are given in Table 1. The solutions were prepared using the supplied 250 mL bottles.

Table 1 – List of solutions prepared for batch contact testing.

Solution ID	Target Concentration Cs (g/L)	Mass CsCl (g)	Mass ASTM Type I (>18 MΩ·cm) (g)
1	0.133	0.03	200.00
2	1.329	0.34	200.00
3	13.290	3.37	200.00

3. The preparation of the solutions was as follows and participants recorded all information in Table 1.:

a) Record the solution ID in Column A and the target Cs Concentration in Column B of Appendix A.
b) Collect the appropriate solution preparation bottle and record the mass of the bottle (with lid) on a balance with 0.01 g precision. Record the value, in g, in Column C of Appendix A.
c) On a separate weigh boat, weigh out the approximate mass of the provided CsCl and add to the previously weighed bottle. Record the mass of the bottle containing the CsCl (with lid) in Column D of Appendix A.
d) Add the required mass of water, using ASTM Type II (> 18 MΩ·cm) and record in Column E of Appendix A.
e) Agitate the solution by hand and allow to sit for > 12 h before contact experiments.
f) Collect a subsample of each solution, filter through the 0.45 µm syringe filter and analyze for Cs concentration. This measured Cs concentration will be used as the initial amount used in the K_d calculation in Appendix B.

2.4 Batch Testing

1. No pretreatment of the soil samples shall be performed.
2. The soil sample has been previously characterized. No characterization is required.
3. An initial K_d test was performed on the Cs sorption. Sorption is expected to reach equilibrium within 24 hours. The test duration will be 7 days.
4. Select a test bottle (60 mL) from the provided set and label with the test number from Table 2.
5. Weigh the empty, labelled bottle and record mass on Row 4 of the corresponding datasheet in Appendix B.
6. Add the corresponding mass of soil from Table 2 to the bottle and record the total mass (soil and bottle) in Row 5 of the datasheet in Appendix B.
7. Add the corresponding amount of Cs-solution from Table 2 to the soil and bottle. Record the mass (solution, soil and bottle) in Row 7 of the datasheet in Appendix B.
8. Record the time of solution addition in Row 9 of the datasheet in Appendix B.
9. Seal the bottle lid and place on an agitator for 7 days.
10. After 7 days remove the bottle from the agitator and allow to settle for 2h. Record the date and time of stopping the agitation in Row 10 of the datasheet in Appendix B.

11. Collect a subsample of the supernatant from the bottle (~ 5 mL) and pass through the 0.45 um syringe filter.
12. Analyze the filtered aliquot for Cs concentration.
13. Measure the pH of the solution in the bottle with the soil and record on Row 14 of the datasheet in Appendix B.
14. Following the pH measurement, discard of the solution and soil using your institution's waste management practices.
15. Complete the calculations in the datasheet. This can be done electronically or manually.
16. Return data to Matthew Asmussen (PNNL) electronically.

Table 2 – List of batch contact tests performed in the round robin.

Test ID	Solution ID	Mass of Soil (g)	Mass of Solution (g)
1	1	1	25
2	1	1	25
3	1	1	25
4	2	1	25
5	2	1	25
6	2	1	25
7	3	1	25
8	3	1	25
9	3	1	25
10	1	0	25
11	2	0	25
12	3	0	25

3.0 Results

The round robin was carried out by nine participating laboratories between January and May 2019. Tests were run for a duration of 7 d; however, prior testing at PNNL and Argonne National Laboratory (unpublished) showed equilibrium is reached after ≈2 h. This time frame ensured equilibrium was reached.

The overall results provided by the participants are given in Table 3. The average measurements between the tests are listed in Table 4. The full datasets returned by the participants are given in Appendix D.

Table 3 – List of the K_d values measured by each participant from the nine tests in the round robin evaluation.

Test	1	2	3	4	5	6	7	8	9
1	275.67	278.94	251.86	232.68	230.04	264.09	52.95	466.15	266.56
2	276.03	277.50	259.43	224.27	257.92	263.63	54.34	435.61	286.26
3	275.52	277.50	249.98	226.93	251.20	269.04	55.96	454.98	265.93
4	36.64	41.36	40.46	33.40	24.45	35.36	38.84	33.68	44.94
5	36.70	41.70	38.54	36.04	30.82	33.67	38.96	32.49	41.94
6	36.85	41.43	36.87	47.60	25.26	33.49	39.56	33.52	42.16
7	2.95	2.05	3.49	4.47	4.31	3.94	2.90	2.43	1.54
8	2.90	2.42	2.92	5.87	4.56	3.95	1.37	1.24	0.21
9	2.78	2.28	2.52	3.64	3.76	3.17	3.37	2.19	0.45

Table 4 – Average K_d measured in each of the round robin evaluations.

Cs Concentration	1	(0.13 mg/L)	2	(1.3 mg/L)	3	(13 mg/L)
Institution	Kd (mL/g)	St.Dev	Kd (mL/g)	St.Dev	Kd (mL/g)	St.Dev
1	275.7	0.3	36.7	0.1	2.9	0.1
2	278.0	0.8	41.5	0.2	2.2	0.2
3	253.8	5.0	38.6	1.8	3.0	0.5
4	228.0	4.3	39.0	7.5	4.7	1.1
5	246.4	14.6	26.8	3.5	4.2	0.4
6	265.6	3.0	34.2	1.0	3.7	0.4
7	54.4	1.5	39.1	0.4	2.5	1.0
8	452.2	15.5	33.2	0.6	2.0	0.6
9	272.9	11.6	43.0	1.7	0.7	0.7
Average	258.6	100.8	36.9	2.4	2.9	0.4
rsd	0.4		0.1		0.1	

The data returned by the participants was further analyzed for isotherm relationships from the concentration changes. Plotting the data in terms of the content of Cs sorbed (in µg Cs/g soil) vs. the solution concentration (in µg/mL) shows a logarithmic relationship in Figure 1. This response is indicative of a Freundlich isotherm, and the linear relationship can be described using Equation (2). The response is comparable to those in the scoping study (Ebert and Petri, 2012):

$$log[Cs]_{soil} = logK_F + \eta log[Cs]_{soln} \quad (2)$$

where:

$[Cs]_{soil}$ concentration of Cs on the soil in µg/g

K_F Freundlich adsorption constant for Cs and the soil

η Freundlich exponent for Cs and the soil

$[Cs]_{soln}$ concentration of Cs in solution in µg/mL

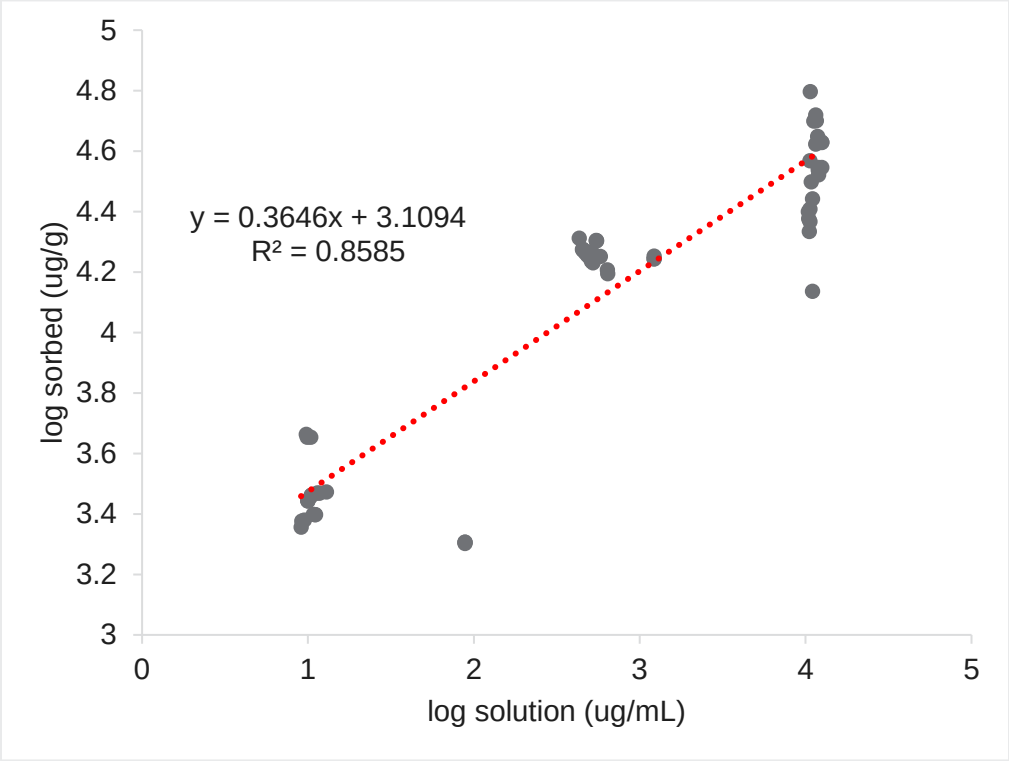

Figure 1 – Plot of the global data from the round robin participants showing Freundlich isotherm behavior.

4.0 Precision and Bias

Based on the results returned by the participants, a precision and bias statement was prepared using the guidance in ASTM Method E691-18 (now E691-19e1) *Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method*. Six statistical parameters were evaluated:

- *repeatability limit (r), n*—the value below which the absolute difference between two individual test results obtained under repeatability conditions may be expected to occur with a probability of approximately 0.95 (95 %). Defined as 2.8 S_r.
- *reproducibility limit (R), n*—the value below which the absolute difference between two test results obtained under reproducibility conditions may be expected to occur with a probability of approximately 0.95 (95 %). Defined as 2.8 S_R.
- $\bar{x}$ is the mean of all runs and $\bar{s}_x$ the standard deviation of that mean.
- S_r is the average standard deviation between triplicate runs at each institution
- S_R is the average standard deviation between the average value of each institution

The precision of the test results and corresponding statistical analyses are shown in Table 5. No bias statement can be produced as there is no available literature value for the sorption of Cs to San Joaquin soil.

Table 5 – Summary of the ASTM C1733 Round Robin precision evaluation.

Test Solution (Cs concentration)	$\bar{x}$	$\bar{s}_x$	s_r	s_R	r	R
A (0.13 mg/L)	258.6	100.8	8.4	101.0	23.4	280.0
B (1.3 mg/L)	36.9	4.9	2.9	5.5	8.1	15.1
C (13 mg/L)	2.9	1.2	0.7	1.3	1.8	3.7

4.1 Precision and Bias Statement to be Included in ASTM C1733 Section 8

8.1 The precision of this test method is based on an interlaboratory study of Cs sorption to San Joaquin soil (Standard Reference Material 2709a), conducted in 2019. Nine laboratories tested three variations of the system. Every "test result" represents an individual determination. Each laboratory was asked to submit three replicate test results, from a single operator, for each system. Practice E691 was followed for the design and analysis of the data; the details are given in Asmussen et al. (7)[1]. The foundation for the round robin test case was provided through scoping tests of Cs sorption to San Joaquin soil (8)[2].

8.1.1. Repeatability limit (r) - Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the "r" value for that material; "r" is the interval representing the

[1] This report

[2] Ebert, W.L. and E.T. Petri. 2012. Uptakes of Cs and Sr on San Joaquin Soil Measured Following ASTM Method C1733. ANL-12/11. Argonne National Laboratory. Lamont, IL.

critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

8.1.1.1 Repeatability limits are listed in the Tables below.

8.1.2 Reproducibility limit (R) - Two test results shall be judged not equivalent if they differ by more than the "R" value for that material; "R" is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

8.1.2.1 Reproducibility limits are listed in the Tables below.

8.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in ASTM Practice E177.

8.1.4. Any judgment in accordance with statements 9.1.1 and 9.1.2 would have an approximate 95% probability of being correct.

Table 1 – Summary of the K_d measurements (mL/g) from the round robin tests for Cs sorption to San Joaquin soil. A, B, C were measurements made from different starting concentrations of Cs. (mg/L in solution)

Solution	$\bar{x}$	$\bar{s}_x$	s_r	s_R	**r**	**R**
A (0.13 mg/L)	258.6	100.8	8.4	101.0	23.4	280.0
B (1.3 mg/L)	36.9	4.9	2.9	5.5	8.1	15.1
C (13 mg/L)	2.9	1.2	0.7	1.3	1.8	3.7

8.2 Other literature examples of intralaboratory studies—Precision results (repeatability) for distribution ratios by short-term batch method for Cd, Hg, Se, and Sr have been reported by Del Debbie and Thomas (8)[1], and are found to be in the range of 1 to 7 %. Fuhrmann, et al. (9)[2] reported K_d values for Cs with a precision (repeatability) of 4 %.

8.3 Bias—Since there is no accepted reference material suitable for determining the bias for the procedure in Test Method C1733, Distribution Coefficients of Inorganic Species by the Batch Method, bias has not been determined.

[1] Del Debbie, J. A., and Thomas, T . R., "Hazardous Properties of Radionuclides and Hazardous Chemical Species in Soils at the Idaho Processing Plant," WINCO-1068, Westinghouse Idaho Nuclear Company, Inc., Idaho Falls, ID, October, 1989.
[2] Fuhrmann, M., Pietrzak, R., Nieheisel, J., and Dyer, R., "Partitioning of Cs-137 Between Sediment and Water from the Black Sea," Chemistry and Ecology, Vol 7, 1992, pp. 3–17.

5.0 References

ASTM C1733-20, Standard Test Method for Distribution Coefficients of Inorganic Species by Batch Method, ASTM International, West Conshohocken, PA, 2020, www.astm.org

ASTM D1193-06(2018), Standard Specification for Reagent Water, ASTM International, West Conshohocken, PA, 2018, www.astm.org

ASTM E691-19e1, Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method, ASTM International, West Conshohocken, PA, 2019, www.astm.org

Ebert, W.L. and E.T. Petri. 2012. Uptakes of Cs and Sr on San Joaquin Soil Measured Following ASTM Method C1733. ANL-12/11. Argonne National Laboratory. Lamont, IL.

Appendix A – Solution Preparation

Col A	Col B	Col C	Col D	Col E
Solution ID	Target Concentration Cs (g/L)	Mass of Empty Bottle (with lid) (g)	Mass of Bottle with CsCl (with lid) (g)	Mass of Bottle with Water and CsCl (with lid) (g)
1				
2				
3				

Date Prepared:_____

Prepared by:_____

Appendix B – Datasheet for Distribution Coefficient Determination

ROW	Test ID:	Performed by:
1	Description of Solid:	San Joaquin Reference Soil
2	Solution ID	
3	Species of Interest:	Cs
4	Mass of Empty Bottle (g)	
5	Total Mass of Bottle and Soil (g)	
6	Mass of Soil (g) ***M,*** (Row 5 – Row 4)	
7	Total Mass of Bottle, Soil and Solution (g)	
8	Total Mass of Solution, ***V***, (Row 7 – Row 5) (g)	
9	Experiment Start Time and Date	
10	Experiment End Time and Date	
11	Filter Material/Pore Size:	0.45 µm
12	Starting Concentration of Tracer in Contact Solution, C_s: *Tests 1-3 – From Solution 1* *Tests 4-6 – From Solution 2* *Tests 7-9 – From Solution 3*	
13	Final Concentration of Tracer in Contact Solution, C_f, and Measurement Technique	
14	Final pH of Contact Solution:	
15	Calculate Quantity of Tracer Sorbed on Solid, Q_s: $Q_s = (V \times C_s) - (V \times C_f)$	
16	Calculate Concentration of Tracer Sorbed on Solid, **S**: $S = \frac{(V \times C_s) - (V \times C_f)}{M} = Q_s/M$	
17	Calculate Distribution Coefficient, K_d: $K_d = \frac{\frac{(V \times C_s) - (V \times C_f)}{M}}{C_f} = S/C_f$	
18	Additional Notes:	

Appendix C – San Joaquin SRM 2709a Composition

The chemical composition listed is taken from the SRM 2709a certificate.

Table 1. Certified Values[a] (Dry-Mass Basis) for Elements in SRM 2709a

Element	Mass Fraction (%)	Coverage Factor, k	Element	Mass Fraction (mg/kg)	Coverage Factor, k
Aluminum (Al)	7.37 ± 0.16	2.04	Antimony (Sb)	1.55 ± 0.06	2.36
Calcium (Ca)	1.91 ± 0.09	2.05	Barium (Ba)	979 ± 28	2.57
Iron (Fe)	3.36 ± 0.07	2.23	Cadmium (Cd)	0.371 ± 0.002	2
Magnesium (Mg)	1.46 ± 0.02	2.02	Chromium (Cr)	130 ± 9	2.05
Phosphorus (P)	0.0688 ± 0.0013	2.12	Cobalt (Co)	12.8 ± 0.2	2.45
Potassium (K)	2.11 ± 0.06	2.45	Lead (Pb)	17.3 ± 0.1	2
Silicon (Si)	30.3 ± 0.4	2.57	Manganese (Mn)	529 ± 18	2.16
Sodium (Na)	1.22 ± 0.03	2.02	Strontium (Sr)	239 ± 6	2.26
Titanium (Ti)	0.336 ± 0.007	2.26	Vanadium (V)	110 ± 11	2.10
			Zirconium (Zr)	195 ± 46	2.10

Table 2. Reference Values[a] (Dry-Mass Basis) for Elements in SRM 2709a

Element	Mass Fraction (mg/kg)
Arsenic (As)	10.5 ± 0.3
Cerium (Ce)	42 ± 1
Cesium (Cs)	5.0 ± 0.1
Copper (Cu)	33.9 ± 0.5
Europium (Eu)	0.83 ± 0.02
Gadolinium (Gd)	3.0 ± 0.1
Lanthanum (La)	21.7 ± 0.4
Mercury (Hg)[b]	0.9 ± 0.2
Nickel (Ni)	85 ± 2
Rubidium (Rb)	99 ± 3
Scandium (Sc)	11.1 ± 0.1
Thallium (Tl)	0.58 ± 0.01
Thorium (Th)	10.9 ± 0.2
Uranium (U)	3.15 ± 0.05
Zinc (Zn)	103 ± 4

Appendix D – Participant Raw Data

Institution 1

TEST ID	CsCl solution	bottle tare	Target CsCl (g)	Actual CsCl (g)		Target water (g)	Actual water (g)		Tare bottle + lid (g)	Soil present (1=yes, 0=no)	Bottle +lid + soil (g)	M Soil (g)	Bottle + lid + soil + water (g)	V Water (g)	Equilibrium Start time (date time)	Equilibrium Stop time (date time)	Equilibrium pH	C_f or C_s Equilibrium Cs (ug/L)	Q_s Sorbed mass (ug)	$S = Q_s/M$ Sorbed conc (ug/g)	K_d K_d (mL/g)		K_d Ave (mL/g)	K_d Stdev. (mL/g)
1	1	33.311	0.03	0.309	33.311	200	200	233.3	14.9708	1	15.975	1.0042	40.9566	24.982	3/26/2019 9:30	4/2/2019 10:30	7	10494.18	2905120.07	2892969.6	275.67		275.7	0.3
2	1		0.03			200			14.9925	1	15.9961	1.0036	40.9764	24.98	3/26/2019 9:30	4/2/2019 10:30	7	10487.46	2905301.72	2894880.15	276.03			
3	1		0.03			200			14.968	1	15.9745	1.0065	41.0033	25.029	3/26/2019 9:30	4/2/2019 10:30	7	10475.77	2905085.56	2886324.45	275.52			
4	2	33.092	0.34	0.341	33.437	200	200	233.4	14.9538	1	15.9546	1.0008	40.9586	25.00	3/26/2019 9:30	4/2/2019 10:30	7	548846.84	20126005.4	20109917.5	36.64		36.7	0.1
5	2		0.34			200			14.9613	1	15.9618	1.0005	40.9766	25.015	3/26/2019 9:30	4/2/2019 10:30	7	548286.31	20134099.4	20124037.3	36.704			
6	2		0.34			200			14.952	1	15.9515	0.9995	40.9672	25.016	3/26/2019 9:30	4/2/2019 10:30	7	547270.87	20159008	20169092.5	36.854			
7	3	33.209	3.37	3.3695	36.581	200	200	236.5	14.9227	1	15.926	1.0033	40.9168	24.991	3/26/2019 9:30	4/2/2019 10:30	7	11897909.78	35237943.6	35122040.8	2.952		2.9	0.1
8	3		3.37			200			14.9547	1	15.9577	1.003	40.9741	25.016	3/26/2019 9:30	4/2/2019 10:30	7	11911494.11	34593526.1	34490055.9	2.8955			
9	3		3.37			200			14.9074	1	15.9118	1.0044	40.9358	25.024	3/26/2019 9:30	4/2/2019 10:30	7	11955475.87	33402399	33256072.3	2.7817			
10	1	33.311	0.03	0.309		200			14.8577	0	14.8577	0	39.8883	25.031	3/26/2019 9:30	4/2/2019 10:30	5	126536.38						
11	2	33.092	0.34	0.341		200			14.9833	0	14.9833	0	39.9966	25.013	3/26/2019 9:30	4/2/2019 10:30	5	1353254.94						
12	3	33.209	3.37	3.3695		200			14.9651	0	14.9651	0	39.9927	25.028	3/26/2019 9:30	4/2/2019 10:30	6	13288378.72						
														DI only										
C1*									14.9855	1	15.983	0.9975	40.97	24.987	3/26/2019 9:30	4/2/2019 10:30	6	<1.00						
C2*									14.925	1	15.9246	0.9996	40.9655	25.041	3/26/2019 9:30	4/2/2019 10:30	7	<1.00						

* Additional controls in which soil + water were added to test tube and carried through to experiment to provide a measure of how much stable Cs was present in the soil, which if present, would require accounting for in Kd calculation. No detectable indigenous Cs desorbed from the sediment.

Institution 2

		[µg/L]	[g/L]	Cs(g/L)	Cf(g/L)	V(g): total mass volume	M(g):Solid Mass	Qs=(VxCs)-(VxCf)	S=Qs/M	Kd=S/Cf
sample-1	Cs	10288.35	0.010288	0.121	0.01	25.13	1	2.78943	2.79	278.94
sample-2	Cs	10412.93	0.010413	0.121	0.01	25	1	2.775	2.78	277.50
sample-3	Cs	10476.35	0.010476	0.121	0.01	25	1	2.775	2.78	277.50
sample-4	Cs	454784	0.454784	1.206	0.455	25.06	1	18.82006	18.82	41.36
sample-5	Cs	452033	0.452033	1.206	0.452	25	1	18.85	18.85	41.70
sample-6	Cs	453948	0.453948	1.206	0.454	25.01	1	18.80752	18.81	41.43
sample-7	Cs	10520010	10.52001	11.382	10.52	25.02	1	21.56724	21.57	2.05
sample-8	Cs	10377760	10.37776	11.382	10.378	25	1	25.1	25.10	2.42
sample-9	Cs	10430750	10.43075	11.382	10.431	25.01	1	23.78451	23.78	2.28
sample-10	Cs	117368.5	0.117369	0.121	0.117	25	0	0.1	0	0
sample-11	Cs	1210974	1.210974	1.206	1.211	25.01	0	-0.12505	0	0
sample-12	Cs	11430560	11.43056	11.382	11.431	25.01	0	-1.22549	0	0
sample-13	Cs	**120783.7**	0.120784	Initial						
sample-14	Cs	**1205803**	1.205803							
sample-15	Cs	**11381510**	11.38151							

Institution 3

Test	Tare (g)	Tare + soil (g)	Tare + soil + sol. (g)	Soil (g)	Sol. (g)	Cs	Cf	Qs	S	Kd
1	14.98	15.93	40.83	0.95	24.9	101000	9520	2277852	2397739	252
2	14.94	15.9	40.77	0.96	24.87	101000	9170	2283812	2378971	259
3	14.98	15.99	40.93	1.01	24.94	101000	9080	2292485	2269787	250
4	15.02	16.01	40.91	0.99	24.9	1200000	460000	18426000	18612121	40.5
5	14.91	15.9	40.81	0.99	24.91	1200000	474000	18084660	18267333	38.5
6	14.97	15.96	40.89	0.99	24.93	1200000	487000	17775090	17954636	36.9
7	14.91	15.93	41.11	1.02	25.18	12100000	10600000	37770000	37029412	3.49
8	14.95	15.99	41.19	1.04	25.2	12100000	10800000	32760000	31500000	2.92
9	14.97	15.97	41.14	1	25.17	12100000	11000000	27687000	27687000	2.52
10	14.99	14.99	39.97	0	24.98	101000	102000	-24980		
11	14.99	14.99	39.91	0	24.92	1200000	1160000	996800		
12	14.97	14.97	40.18	0	25.21	12100000	12200000	-2521000		

Institution 4

Col A	Col B	Col C	Col D	Col E			
Solution ID	Target Concentration Cs	Mass of Empty Bottle (with lid)	Mass of Bottle with CsCl (with lid)	Mass of Bottle with Water and CsCl (with lid)	Mass of CsCl	mass of wat	ICP-OES Concentrations (g/L)
	(g/L)	(g)	(g)	(g)			
1	0.133	33.1757	33.2082	233.22	0.0325	200.0118	0.111012407
2	1.329	33.3001	33.6418	233.65	0.3417	200.0082	1.252706721
3	13.29	33.2591	36.5809	236.58	3.3218	199.9991	13.19083784

ROW	Test ID: 1	Performed by:	
1	Description of Solid:	San Joaquin Reference Soil	
2	Solution ID	1	
3	Species of Interest:	Cs	
4	Mass of Empty Bottle (g)	11.7034	
5	Total Mass of Bottle and Soil (g)	12.7036	
6	Mass of Soil (g) ***M***, (Row 5 – Row 4)	1.0002	
7	Total Mass of Bottle, Soil and Solution (g)	37.7158	
8	Total Mass of Solution, ***V***, (Row 7 – Row 5) (g)	25.0122	
9	Experiment Start Time and Date	11:07AM 2/19/19	
10	Experiment End Time and Date	11:30AM 2/26/19	
11	Filter Material/Pore Size:	0.45 µm	
12	Starting Concentration of Tracer in Contact Solution, C_s:	0.111	g/L
13	Final Concentration of Tracer in Contact Solution, C_f, and Measurement Technique	0.010773	g/L
14	Final pH of Contact Solution:	8.46	
15	Calculate Quantity of Tracer Sorbed on Solid, Q_s:	2.5072	g^2/L
16	Calculate Concentration of Tracer Sorbed on Solid, **S**:	2.5067	g/L
17	Calculate Distribution Coefficient, K_d:	232.6794	
18	Additional Notes:		

ROW	Test ID: 2	Performed by:	
1	Description of Solid:	San Joaquin Reference Soil	
2	Solution ID	1	
3	Species of Interest:	Cs	
4	Mass of Empty Bottle (g)	11.7197	
5	Total Mass of Bottle and Soil (g)	12.7204	
6	Mass of Soil (g) ***M***, (Row 5 – Row 4)	1.0007	
7	Total Mass of Bottle, Soil and Solution (g)	37.7365	
8	Total Mass of Solution, ***V***, (Row 7 – Row 5) (g)	25.0161	
9	Experiment Start Time and Date	11:11AM 2/19/19	
10	Experiment End Time and Date	11:30AM 2/26/19	
11	Filter Material/Pore Size:	0.45 µm	
12	Starting Concentration of Tracer in Contact Solution, C_s:	0.111	g/L
13	Final Concentration of Tracer in Contact Solution, C_f, and Measurement Technique	0.011133	g/L
14	Final pH of Contact Solution:	8.55	
15	Calculate Quantity of Tracer Sorbed on Solid, Q_s:	2.4986	g^2/L
16	Calculate Concentration of Tracer Sorbed on Solid, **S**:	2.4968	g/L
17	Calculate Distribution Coefficient, K_d:	224.2669	
18	Additional Notes:		

ROW	Test ID: 3	Performed by:	
1	Description of Solid:	San Joaquin Reference Soil	
2	Solution ID	1	
3	Species of Interest:	Cs	
4	Mass of Empty Bottle (g)	11.7219	
5	Total Mass of Bottle and Soil (g)	12.7223	
6	Mass of Soil (g) ***M***, (Row 5 – Row 4)	1.0004	
7	Total Mass of Bottle, Soil and Solution (g)	37.7367	
8	Total Mass of Solution, ***V***, (Row 7 – Row 5) (g)	25.0144	
9	Experiment Start Time and Date	11:13AM 2/19/19	
10	Experiment End Time and Date	11:30AM 2/26/19	
11	Filter Material/Pore Size:	0.45 µm	
12	Starting Concentration of Tracer in Contact Solution, C_s:	0.111	g/L
13	Final Concentration of Tracer in Contact Solution, C_f, and Measurement Technique	0.011018	g/L
14	Final pH of Contact Solution:	8.57	
15	Calculate Quantity of Tracer Sorbed on Solid, Q_s:	2.5013	g^2/L
16	Calculate Concentration of Tracer Sorbed on Solid, **S**:	2.5003	g/L
17	Calculate Distribution Coefficient, K_d:	226.9250	
18	Additional Notes:		

ROW	Test ID: 4	Performed by:	
1	Description of Solid:	San Joaquin Reference Soil	
2	Solution ID	2	
3	Species of Interest:	Cs	
4	Mass of Empty Bottle (g)	11.7334	
5	Total Mass of Bottle and Soil (g)	12.7346	
6	Mass of Soil (g) ***M***, (Row 5 – Row 4)	1.0012	
7	Total Mass of Bottle, Soil and Solution (g)	37.7274	
8	Total Mass of Solution, ***V***, (Row 7 – Row 5) (g)	24.9928	
9	Experiment Start Time and Date	11:20AM 2/19/19	
10	Experiment End Time and Date	11:30AM 2/26/19	
11	Filter Material/Pore Size:	0.45 µm	
12	Starting Concentration of Tracer in Contact Solution, C_s:	1.2527	g/L
13	Final Concentration of Tracer in Contact Solution, C_f, and Measurement Technique	0.53576	g/L
14	Final pH of Contact Solution:	8.16	
15	Calculate Quantity of Tracer Sorbed on Solid, Q_s:	17.9185	g^2/L
16	Calculate Concentration of Tracer Sorbed on Solid, **S**:	17.8970	g/L
17	Calculate Distribution Coefficient, K_d:	33.4049	
18	Additional Notes:		

ROW	Test ID: 5	Performed by:	
1	Description of Solid:	San Joaquin Reference Soil	
2	Solution ID	2	
3	Species of Interest:	Cs	
4	Mass of Empty Bottle (g)	11.6973	
5	Total Mass of Bottle and Soil (g)	12.6978	
6	Mass of Soil (g) ***M***, (Row 5 – Row 4)	1.0005	
7	Total Mass of Bottle, Soil and Solution (g)	37.728	
8	Total Mass of Solution, ***V***, (Row 7 – Row 5) (g)	25.0302	
9	Experiment Start Time and Date	11:22AM 2/19/19	
10	Experiment End Time and Date	11:30AM 2/26/19	
11	Filter Material/Pore Size:	0.45 µm	
12	Starting Concentration of Tracer in Contact Solution, C_s:	1.2527	g/L
13	Final Concentration of Tracer in Contact Solution, C_f, and Measurement Technique	0.51327	g/L
14	Final pH of Contact Solution:	8.19	
15	Calculate Quantity of Tracer Sorbed on Solid, Q_s:	18.5082	g^2/L
16	Calculate Concentration of Tracer Sorbed on Solid, **S**:	18.4990	g/L
17	Calculate Distribution Coefficient, K_d:	36.0415	
18	Additional Notes:		

ROW	Test ID: 6	Performed by:	
1	Description of Solid:	San Joaquin Reference Soil	
2	Solution ID	2	
3	Species of Interest:	Cs	
4	Mass of Empty Bottle (g)	11.7196	
5	Total Mass of Bottle and Soil (g)	12.7213	
6	Mass of Soil (g) ***M***, (Row 5 – Row 4)	1.0017	
7	Total Mass of Bottle, Soil and Solution (g)	37.7247	
8	Total Mass of Solution, ***V***, (Row 7 – Row 5) (g)	25.0034	
9	Experiment Start Time and Date	11:24AM 2/19/19	
10	Experiment End Time and Date	11:30AM 2/26/19	
11	Filter Material/Pore Size:	0.45 µm	
12	Starting Concentration of Tracer in Contact Solution, C_s:	1.2527	g/L
13	Final Concentration of Tracer in Contact Solution, C_f, and Measurement Technique	0.43095	g/L
14	Final pH of Contact Solution:	8.19	
15	Calculate Quantity of Tracer Sorbed on Solid, Q_s:	20.5467	g^2/L
16	Calculate Concentration of Tracer Sorbed on Solid, **S**:	20.5118	g/L
17	Calculate Distribution Coefficient, K_d:	47.5968	
18	Additional Notes:		

ROW	Test ID: 10	Performed by:	
1	Description of Solid:	San Joaquin Reference Soil	
2	Solution ID	1	
3	Species of Interest:	Cs	
4	Mass of Empty Bottle (g)	11.695	
5	Total Mass of Bottle and Soil (g)		
6	Mass of Soil (g) ***M***, (Row 5 – Row 4)		
7	Total Mass of Bottle, Soil and Solution (g)	36.7146	
8	Total Mass of Solution, ***V***, (Row 7 – Row 5) (g)	25.0196	
9	Experiment Start Time and Date	11:16AM 2/19/19	
10	Experiment End Time and Date	11:30AM 2/26/19	
11	Filter Material/Pore Size:	0.45 µm	
12	Starting Concentration of Tracer in Contact Solution, C_s:	0.1110	g/L
13	Final Concentration of Tracer in Contact Solution, C_f, and Measurement Technique	0.10980	g/L
14	Final pH of Contact Solution:	6.18	
15	Calculate Quantity of Tracer Sorbed on Solid, Q_s:	0.03041	g^2/L
16	Calculate Concentration of Tracer Sorbed on Solid, **S**:		
17	Calculate Distribution Coefficient, K_d:		
18	Additional Notes:		

ROW	Test ID: 11	Performed by:	
1	Description of Solid:	San Joaquin Reference Soil	
2	Solution ID	2	
3	Species of Interest:	Cs	
4	Mass of Empty Bottle (g)	11.724	
5	Total Mass of Bottle and Soil (g)		
6	Mass of Soil (g) ***M***, (Row 5 – Row 4)		
7	Total Mass of Bottle, Soil and Solution (g)	36.725	
8	Total Mass of Solution, ***V***, (Row 7 – Row 5) (g)	25.001	
9	Experiment Start Time and Date	11:26AM 2/19/19	
10	Experiment End Time and Date	11:30AM 2/26/19	
11	Filter Material/Pore Size:	0.45 µm	
12	Starting Concentration of Tracer in Contact Solution, C_s:	1.2527	g/L
13	Final Concentration of Tracer in Contact Solution, C_f, and Measurement Technique	1.22039	g/L
14	Final pH of Contact Solution:	6.31	
15	Calculate Quantity of Tracer Sorbed on Solid, Q_s:	0.8080	g^2/L
16	Calculate Concentration of Tracer Sorbed on Solid, **S**:		
17	Calculate Distribution Coefficient, K_d:		
18	Additional Notes:		

ROW	Test ID: 12	Performed by:	
1	Description of Solid:	San Joaquin Reference Soil	
2	Solution ID	3	
3	Species of Interest:	Cs	
4	Mass of Empty Bottle (g)	11.6996	
5	Total Mass of Bottle and Soil (g)		
6	Mass of Soil (g) ***M***, (Row 5 – Row 4)		
7	Total Mass of Bottle, Soil and Solution (g)	36.7014	
8	Total Mass of Solution, ***V***, (Row 7 – Row 5) (g)	25.0018	
9	Experiment Start Time and Date	11:26AM 2/19/19	
10	Experiment End Time and Date	11:30AM 2/26/19	
11	Filter Material/Pore Size:	0.45 µm	
12	Starting Concentration of Tracer in Contact Solution, C_s:	13.1908	g/L
13	Final Concentration of Tracer in Contact Solution, C_f, and Measurement Technique	11.84219	g/L
14	Final pH of Contact Solution:	7.62	
15	Calculate Quantity of Tracer Sorbed on Solid, Q_s:	33.7186	g^2/L
16	Calculate Concentration of Tracer Sorbed on Solid, **S**:		
17	Calculate Distribution Coefficient, K_d:		
18	Additional Notes:		

Institution 5

Test ID	Bottle tare, g	+ glass, g	+ glass + soln, g	glass, g	soln, g	Time initiated	Time terminated	Final mass, g	Vessel change, g	Bottle tare, g	+ filtered soln, g	+ soln + HNO3, g	dilution factor	Measured pH	Actual pH		Initial Cs, ug		ACL Cs ppb	dil. corr. Cs ppm	Final Cs, µg	Sorbed Cs, µg	Sorbed Cs, µg/g	Dissolved Cs, µg/mL	sorb/dis mL/g	mean	std. dev.	rsd
				M	V	2/15/2019	2/22/2019										C_s		ICP-MS		C_f	Q_s	S		K_d			
SJRR-1	14.95	15.95	41.04	1.00	25.09	8:22	8:15	41.04	0.00	11.28	24.57	24.61	1.00301	9.20	8.41		3294		12.9	12.9	325	2970	2970	12.9	230			
SJRR-2	14.99	16.01	41.07	1.02	25.06	8:23	8:17	41.07	0.00	11.23	24.41	24.46	1.00379	9.19	8.39		3290		11.4	11.4	287	3004	2945	11.4	258	246	15	5.9%
SJRR-3	15.06	16.08	41.18	1.02	25.10	8:24	8:19	41.17	-0.01	11.19	23.26	23.30	1.00331	9.20	8.41		3296		11.7	11.7	295	3001	2942	11.7	251			
SJRR-4	14.97	16.00	41.08	1.03	25.08	8:25	8:24	41.07	-0.01	11.19	24.45	24.50	1.00377	8.86	8.06		32201		639	641	16087	16115	15645	640	24.4			
SJRR-5	15.01	16.00	41.08	0.99	25.08	8:26	8:26	41.08	0.00	11.26	25.47	24.51	0.93244	8.89	8.09		32201		622	580	14546	17655	17834	579	30.8	26.8	3.5	12.9%
SJRR-6	14.98	15.98	41.02	1.00	25.04	8:27	8:28	41.03	0.01	11.25	24.49	24.53	1.00302	8.94	8.14		32150		638	640	16024	16126	16126	638	25.3			
SJRR-7	14.98	15.98	41.05	1.00	25.07	8:28	8:32	41.05	0.00	11.24	24.97	25.03	1.00437	8.81	8.01		342194		11600	11651	292083	50111	50111	11624	4.31			
SJRR-8	14.94	15.95	40.98	1.01	25.03	8:29	8:34	40.98	0.00	11.21	25.19	25.23	1.00286	8.91	8.11		341648		11500	11533	288669	52979	52455	11506	4.56	4.21	0.41	9.7%
SJRR-9	14.93	15.94	40.96	1.01	25.02	8:30	8:36	40.96	0.00	11.20	24.60	24.66	1.00448	8.90	8.10		341511		11800	11853	296558	44953	44508	11826	3.76			
SJRR-10	14.96		39.98		25.02	8:25	8:13	39.98	0.00	11.26	24.52	24.55	1.00226	9.67	8.88				131	131								
SJRR-11	14.96		40.03		25.07	8:28	8:22	40.02	-0.01	11.26	24.26	24.30	1.00308	9.05	8.25				1280	1284								
SJRR-12	14.95		39.96		25.01	8:31	8:31	39.96	0.00	11.18	24.91	24.96	1.00364	9.17	8.37				13600	13650								

$$\log [Cs]_{soil} = \log K_F + n \log [Cs$$

Institution 6

Solutions

ID	Target Cs	Empty	E + CsCl	E+CsCl+W	CsCl	H2O	Calc Cs	ICP LIMS	ICP Cs	ICP Cs
-	*g/L*	*g*	*g*	*g*	*g*	*g*	*g/L*	-	*ppm*	*g/L*
1	0.133	33.52	33.55	233.56	0.03	200.01	0.12	1902009-01	88.5	0.0885
2	1.329	33.33	33.68	233.71	0.35	200.03	1.38	1902009-02	1220	1.22
3	13.29	33.35	36.76	236.80	3.41	200.04	13.46	1902009-03	12500	12.5

Experiments

ID	Soltn ID	Empty	E+Soil	E+S+W	Soil	Water	Final pH	ICP LIMS	ICP end Cs	ICP end Cs	ICP start Cs	Qs	S	Kd	
-	-	*g*	*g*	*g*	*g*	*g*	*Room T*	-	*ppm*	*g/L*	*g/L*	*g*	*g/g*	*L/g*	*mL/g*
1	1	15.11	16.11	41.17	1.00	25.06	8.078	1902009-04	7.67	0.00767	0.0885	0.002026	0.002026	2.6E-01	2.6E+02
2	1	15.20	16.21	41.26	1.01	25.05	8.343	1902009-05	7.61	0.00761	0.0885	0.002026	0.002006	2.6E-01	2.6E+02
3	1	15.19	16.19	41.21	1.00	25.02	8.372	1902009-06	7.53	0.00753	0.0885	0.002026	0.002026	2.7E-01	2.7E+02
4	2	15.15	16.15	41.21	1.00	25.06	7.947	1902009-07	506	0.506	1.22	0.017893	0.017893	3.5E-02	3.5E+01
5	2	15.19	16.19	41.20	1.00	25.01	7.987	1902009-08	520	0.52	1.22	0.017507	0.017507	3.4E-02	3.4E+01
6	2	15.16	16.16	41.37	1.00	25.21	7.962	1902009-09	524	0.524	1.22	0.017546	0.017546	3.3E-02	3.3E+01
7	3	15.12	16.12	41.12	1.00	25.00	8.027	1902009-10	10800	10.8	12.5	0.0425	0.0425	3.9E-03	3.9E+00
8	3	15.14	16.14	41.23	1.00	25.09	7.908	1902009-11	10800	10.8	12.5	0.042653	0.042653	3.9E-03	3.9E+00
9	3	15.17	16.17	41.28	1.00	25.11	-	1902009-12	11100	11.1	12.5	0.035154	0.035154	3.2E-03	3.2E+00
10	1	15.12	15.12	40.13	0.00	25.01	7.111	1902009-13	84.6	0.0846	0.0885	9.75E-05	*NA*	*NA*	*NA*
11	2	15.11	15.11	40.14	0.00	25.03	6.943	1902009-14	1190	1.19	1.22	0.000751	*NA*	*NA*	*NA*
12	3	15.12	15.12	40.18	0.00	25.06	7.527	1902009-15	12400	12.4	12.5	0.002506	*NA*	*NA*	*NA*

Data

M(Cs)	132.905	g/mol
M(Cl)	35.453	g/mol

Institution 7

Solution ID	1	2	3	4	5	6	7	8	9	10	11	12
Mass of Empty Bottle (g)	15.1945	15.1617	15.1958	15.1508	15.197	15.198	15.1844	15.1492	15.1513	15.203	15.1483	15.1936
Total Mass of Bottle and soil (g)	16.1863	16.1587	16.195	16.1472	16.1908	16.1903	16.1756	16.1438	16.1502			
Mass of Soil (g)	0.9918	0.997	0.9992	0.9964	0.9938	0.9923	0.9912	0.9946	0.9989			
Total Mass of Bottle, Soil and Solution (g)	41.6504	41.2251	42.0666	41.1878	41.2443	41.3397	41.7109	41.3728	41.3531	40.2129	40.1526	40.4028
Total Mass of solution (g)	25.4641	25.0664	25.8716	25.0406	25.0535	25.1494	25.5353	25.229	25.2029	25.0099	25.0043	25.2092
Starting concentration (g/L)*	0.098	0.098	0.098	0.84	0.84	0.84	7.81	7.81	7.81	0.098	0.84	7.81
Final concentration (g/L)*	0.032	0.031	0.031	0.33	0.33	0.328	7.02	7.41	6.89	0.098	0.82	7.93
Final pH of Contact solution	8.375	8.396	8.546	8.186	8.191	8.209	8.188	8.273	8.254	5.99	6.473	7.439
Quantity of Tracer Sorbed (g)	0.002	0.002	0.002	0.013	0.013	0.013	0.020	0.010	0.023	0.000	0.001	-0.003
Concentration of tracer sorbed (g/g)	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.01	0.02			
Distribution coefficient (mL/g)	53.0	54.3	56.0	38.8	39.0	39.6	2.9	1.4	3.4			
notes:												
Experiments started at 4:32 pm on 2/6/19	Average	54.4		Average	39.1		Average	2.5				
Experiments stopped at 11:20 pm on 2/15/19 (due to weather)	Stdev	1.50		Stdev	0.39		Stdev	1.05				
	%RSD	3%		%RSD	1%		%RSD	41%				

Institution 8

Test ID	Solution ID	Empty bottle (g)	Bottle + soil (g)	Soil (g) (**M**)	Bottle + soil + soln (g)	Solution (g) (**V**)	Exp start	Exp stop	Filter material/pore size (µm)	Starting [Cs] (g/L) (**Cs**)	Final [Cs] (g/L) (**Cf**)	Final pH**	Tracer sorbed on solid (**Qs**)	Concentration tracer sorbed on solid (g/L) (**S**)	Distribution coefficient (**Kd**)	Additional notes
1	1	14.9573	15.9587	1.0014	41.1267	25.1680	3/21/2019 7:28	3/28/2019 10:27	0.45	1.91E-02	9.76E-04	8.03	0.46	0.46	466.15	18.2 MΩ cm water used
2	1	14.9364	15.9352	0.9988	40.9779	25.0427	3/21/2019 7:33	3/28/2019 10:27	0.45	1.91E-02	1.04E-03	8.1	0.45	0.45	435.61	18.2 MΩ cm water used
3	1	14.986	15.9899	1.0039	41.0314	25.0415	3/21/2019 7:39	3/28/2019 10:27	0.45	1.91E-02	9.92E-04	8.14	0.45	0.45	454.98	18.2 MΩ cm water used
4	2	14.9808	15.9887	1.0079	41.0091	25.0204	3/21/2019 7:51	3/28/2019 10:27	0.45	1.21E-01	5.12E-02	7.82	1.74	1.72	33.68	18.2 MΩ cm water used
5	2	14.9938	16.0003	1.0065	41.008	25.0077	3/21/2019 7:55	3/28/2019 10:27	0.45	1.21E-01	5.23E-02	7.83	1.71	1.70	32.49	18.2 MΩ cm water used
6	2	14.9875	15.9891	1.0016	40.9873	24.9982	3/21/2019 8:00	3/28/2019 10:27	0.45	1.21E-01	5.15E-02	7.86	1.73	1.73	33.52	18.2 MΩ cm water used
7	3	14.9612	15.9651	1.0039	40.9843	25.0192	3/21/2019 8:05	3/28/2019 10:27	0.45	1.16E+00	1.06E+00	7.98	2.57	2.56	2.43	18.2 MΩ cm water used
8	3	14.9645	15.9663	1.0018	40.9672	25.0009	3/21/2019 8:09	3/28/2019 10:27	0.45	1.16E+00	1.10E+00	8.02	1.37	1.37	1.24	18.2 MΩ cm water used
9	3	14.859	15.8678	1.0088	40.8777	25.0099	3/21/2019 8:13	3/28/2019 10:27	0.45	1.16E+00	1.06E+00	7.97	2.35	2.33	2.19	18.2 MΩ cm water used
10	1	14.9463	14.9463	0	39.9695	25.0232	3/21/2019 7:42	3/28/2019 10:27	0.45	1.91E-02	1.13E-02	7.13	0.19	#DIV/0!	#DIV/0!	18.2 MΩ cm water used
11	2	14.9916	14.9916	0	40.0295	25.0379	3/21/2019 7:46	3/28/2019 10:27	0.45	1.21E-01	1.21E-01	7.07	-0.01	#DIV/0!	#DIV/0!	18.2 MΩ cm water used
12	3	14.9687	14.9687	0	39.9687	25.0000	3/21/2019 8:15	3/28/2019 10:27	0.45	1.16E+00	1.20E+00	7.58	-1.05	#DIV/0!	#DIV/0!	18.2 MΩ cm water used

Institution 9

Row	Test ID 1	
1	Description of solid	San Joaquin Reference Soil
2	Solution ID	1
3	Species of Interest	Cs
4	Mass of Empty Bottle (g)	14.88
5	Total mass of bottle and soil (g)	15.4
6	Mass of soil (g) **M**, (Row 5 - Row 4)	0.96
7	Total mass of bottle, soil and solution (g)	40.9
8	Total mass of solution, **V**, (Row7-Row5) (g)	25.06
9	Experiment start time and date	12:10 pm March 1st 2019
10	Experiment end time and data	12:00 pmMarch 8th 2019
11	Filter material/Pore size	0.45
12	Starting concentration of tracer in contact solution **Cs** (g/L)	
	Tests 1-3 - From solution 1	0.139550752
	Test 4-6 - From solution 2	
	Test 7-9 - From solution 3	
13	Final concentration of tracer in contact solution, **Cf**	0.01244739
	and measurment technique	ICP MS
14	Final pH of contact solution	7.8
15	Calculate quantity of tracer sorbed on soild, **Qs**	
	Qs= (VxCs) x (VxCf)	0.00318521
16	Calculate concentration of tracer sorbed on solid S: $S=\frac{Q_s}{M}$	0.003317927
17	Calculate distribution coefficient, **Kd** $K_d=\frac{S}{C_f}$	0.266556069
18	Additional notes:	Converted unit of V grams to L assuming 1g/ml
		concentration in g/L (Cs) From ICP MS

Test ID 2	
Description of solid	San Joaquin Reference Soil
Solution ID	1
Species of Interest	Cs
Mass of Empty Bottle (g)	14.9
Total mass of bottle and soil (g)	15.8
Mass of soil (g) **M**, (Row 5 - Row 4)	0.9
Total mass of bottle, soil and solution (g)	40.8
Total mass of solution, **V**, (Row7-Row5) (g)	25
Experiment start time and date	12:10 pm March 1st 2019
Experiment end time and data	12:00 pmMarch 8th 2019
Filter material/Pore size	0.45
Starting concentration of tracer in contact solution **Cs**	
Tests 1-3 - From solution 1	0.139550752
Test 4-6 - From solution 2	
Test 7-9 - From solution 3	
Final concentration of tracer in contact solution, **Cf**	0.0123437050
and measurment technique	ICP MS
Final pH of contact solution	7.85
Calculate quantity of tracer sorbed on soild, **Qs**	
Qs= (VxCs) x (VxCf)	0.003180176
Calculate concentration of tracer sorbed on solid S: $S=\frac{Q_s}{M}$	0.003533529
Calculate distribution coefficient, **Kd** $K_d=\frac{S}{C_f}$	0.286261628
Additional notes:	Converted unit of V grams to L assuming 1g/ml
	concentration in g/L (Cs) From ICP MS

Row	Test ID 3	
1	Description of solid	San Joaquin Reference Soil
2	Solution ID	1
3	Species of Interest	Cs
4	Mass of Empty Bottle (g)	14.84
5	Total mass of bottle and soil (g)	15.8
6	Mass of soil (g) **M**, (Row 5 - Row 4)	0.96
7	Total mass of bottle, soil and solution (g)	40.78
8	Total mass of solution, **V**, (Row7-Row5) (g)	24.98
9	Experiment start time and date	12:10 pm March 1st 2019
10	Experiment end time and data	12:00 pmMarch 8th 2019
11	Filter material/Pore size	0.45
12	Starting concentration of tracer in contact solution **Cs**	
	Tests 1-3 - From solution 1	0.139550752
	Test 4-6 - From solution 2	
	Test 7-9 - From solution 3	
13	Final concentration of tracer in contact solution, **Cf**	0.01243751
	and measurment technique	ICP-MS
14	Final pH of contact solution	7.93
15	Calculate quantity of tracer sorbed on soild, **Qs**	
	Qs= (VxCs) x (VxCf)	0.003175289
16	Calculate concentration of tracer sorbed on solid S: $S=\frac{Q_s}{M}$	0.003307592
17	Calculate distribution coefficient, **Kd** $K_d=\frac{S}{C_f}$	0.26593687
18	Additional notes:	Converted unit of V grams to L assuming 1g/ml
		concentration in g/L (Cs) From ICP MS

Row	Test ID 4	
1	Description of solid	San Joaquin Reference Soil
2	Solution ID	2
3	Species of Interest	Cs
4	Mass of Empty Bottle (g)	14.9
5	Total mass of bottle and soil (g)	15.9
6	Mass of soil (g) **M**, (Row 5 - Row 4)	1
7	Total mass of bottle, soil and solution (g)	40.94
8	Total mass of solution, **V**, (Row7-Row5) (g)	25.04
9	Experiment start time and date	12:10 pm March 1st 2019
10	Experiment end time and data	12:00 pmMarch 8th 2019
11	Filter material/Pore size	0.45
12	Starting concentration of tracer in contact solution **Cs**	
	Tests 1-3 - From solution 1	
	Test 4-6 - From solution 2	1.218616633
	Test 7-9 - From solution 3	
13	Final concentration of tracer in contact solution, **Cf**	0.436016247
	and measurment technique	ICP Ms
14	Final pH of contact solution	8.06
15	Calculate quantity of tracer sorbed on soild, **Qs**	
	Qs= (VxCs) x (VxCf)	0.019596314
16	Calculate concentration of tracer sorbed on solid S: $S=\frac{Q_s}{M}$	0.019596314
17	Calculate distribution coefficient, **Kd** $K_d=\frac{S}{C_f}$	0.044943999
18	Additional notes:	Converted unit of V grams to L assuming 1g/ml
		concentration in g/L (Cs) From ICP MS

Row	Test ID 5		Row	Test ID 6	
1	Description of solid	San Joaquin Reference Soil	1	Description of solid	San Joaquin Reference Soil
2	Solution ID	2	2	Solution ID	2
3	Species of Interest	Cs	3	Species of Interest	Cs
4	Mass of Empty Bottle (g)	14.94	4	Mass of Empty Bottle (g)	14.9
5	Total mass of bottle and soil (g)	15.92	5	Total mass of bottle and soil (g)	15.92
6	Mass of soil (g) **M**, (Row 5 - Row 4)	0.98	6	Mass of soil (g) **M**, (Row 5 - Row 4)	1.02
7	Total mass of bottle, soil and solution (g)	41	7	Total mass of bottle, soil and solution (g)	40.92
8	Total mass of solution, **V**, (Row7-Row5) (g)	25.08	8	Total mass of solution, **V**, (Row7-Row5) (g)	25
9	Experiment start time and date	12:10 pm March 1st 2019	9	Experiment start time and date	12:10 pm March 1st 2019
10	Experiment end time and data	12:00 pmMarch 8th 2019	10	Experiment end time and data	12:00 pmMarch 8th 2019
11	Filter material/Pore size	0.45	11	Filter material/Pore size	0.45
12	Starting concentration of tracer in contact solution **Cs**		12	Starting concentration of tracer in contact solution **Cs**	
	Tests 1-3 - From solution 1			Tests 1-3 - From solution 1	
	Test 4-6 - From solution 2	1.218616633		**Test 4-6 - From solution 2**	1.218616633
	Test 7-9 - From solution 3			Test 7-9 - From solution 3	
13	Final concentration of tracer in contact solution, **Cf**	0.461767057	13	Final concentration of tracer in contact solution, **Cf**	0.44800104
	and measurment technique	ICP MS		and measurment technique	ICP MS
14	Final pH of contact solution	8.06	14	Final pH of contact solution	7.93
15	Calculate quantity of tracer sorbed on soild, **Qs**		15	Calculate quantity of tracer sorbed on soild, **Qs**	
	Qs= (VxCs) x (VxCf)	0.018981787		Qs= (VxCs) x (VxCf)	0.01926539
16	Calculate concentration of tracer sorbed on solid S: $S=\frac{Q_s}{M}$	0.019369171	16	Calculate concentration of tracer sorbed on solid S: $S=\frac{Q_s}{M}$	0.018887637
17	Calculate distribution coefficient, **Kd** $K_d=\frac{S}{C_f}$	0.041945761	17	Calculate distribution coefficient, **Kd** $K_d=\frac{S}{C_f}$	0.042159806
18	Additional notes:	Converted unit of V grams to L assuming 1g/ml	18	Additional notes:	Converted unit of V grams to L assuming 1g/ml
		concentration in g/L (Cs) From ICP MS			concentration in g/L (Cs) From ICP MS

Row	Test ID 7	
1	Description of solid	San Joaquin Reference Soil
2	Solution ID	3
3	Species of Interest	Cs
4	Mass of Empty Bottle (g)	14.96
5	Total mass of bottle and soil (g)	15.96
6	Mass of soil (g) **M**, (Row 5 - Row 4)	1
7	Total mass of bottle, soil and solution (g)	40.98
8	Total mass of solution, **V**, (Row7-Row5) (g)	25.02
9	Experiment start time and date	12:10 pm March 1st 2019
10	Experiment end time and data	12:00 pmMarch 8th 2019
11	Filter material/Pore size	0.45
12	Starting concentration of tracer in contact solution **Cs**	
	Tests 1-3 - From solution 1	
	Test 4-6 - From solution 2	
	Test 7-9 - From solution 3	16.37752742
13	Final concentration of tracer in contact solution, **Cf**	15.4270737
	and measurment technique	ICP MS
14	Final pH of contact solution	8.31
15	Calculate quantity of tracer sorbed on soild, **Qs**	
	Qs= (VxCs) x (VxCf)	0.023780352
16	Calculate concentration of tracer sorbed on solid S: $S=\frac{Q_s}{M}$	0.023780352
17	Calculate distribution coefficient, **Kd** $K_d=\frac{S}{C_f}$	0.001541469
18	Additional notes:	Converted unit of V grams to L assuming 1g/ml
		concentration in g/L (Cs) From ICP MS

Row	Test ID 8	
1	Description of solid	San Joaquin Reference Soil
2	Solution ID	3
3	Species of Interest	Cs
4	Mass of Empty Bottle (g)	14.9
5	Total mass of bottle and soil (g)	15.92
6	Mass of soil (g) **M**, (Row 5 - Row 4)	1.02
7	Total mass of bottle, soil and solution (g)	41
8	Total mass of solution, **V**, (Row7-Row5) (g)	25.08
9	Experiment start time and date	12:10 pm March 1st 2019
10	Experiment end time and data	12:00 pmMarch 8th 2019
11	Filter material/Pore size	0.45
12	Starting concentration of tracer in contact solution **Cs**	
	Tests 1-3 - From solution 1	
	Test 4-6 - From solution 2	
	Test 7-9 - From solution 3	16.37752742
13	Final concentration of tracer in contact solution, **Cf**	16.23917874
	and measurment technique	ICP MS
14	Final pH of contact solution	8.39
15	Calculate quantity of tracer sorbed on soild, **Qs**	
	Qs= (VxCs) x (VxCf)	0.003469785
16	Calculate concentration of tracer sorbed on solid S: $S=\frac{Q_s}{M}$	0.00340175
17	Calculate distribution coefficient, **Kd** $K_d=\frac{S}{C_f}$	0.000209478
18	Additional notes:	Converted unit of V grams to L assuming 1g/ml
		concentration in g/L (Cs) From ICP MS

Row	Test ID 9	
1	Description of solid	San Joaquin Reference Soil
2	Solution ID	3
3	Species of Interest	Cs
4	Mass of Empty Bottle (g)	14.86
5	Total mass of bottle and soil (g)	15.9
6	Mass of soil (g) **M**, (Row 5 - Row 4)	1.04
7	Total mass of bottle, soil and solution (g)	40.96
8	Total mass of solution, **V**, (Row7-Row5) (g)	25.06
9	Experiment start time and date	12:10 pm March 1st 2019
10	Experiment end time and data	12:00 pmMarch 8th 2019
11	Filter material/Pore size	0.45
12	Starting concentration of tracer in contact solution **Cs**	
	Tests 1-3 - From solution 1	
	Test 4-6 - From solution 2	
	Test 7-9 - From solution 3	16.37752742
13	Final concentration of tracer in contact solution, **Cf**	16.07552302
	and measurment technique	ICP MS
14	Final pH of contact solution	8.39
15	Calculate quantity of tracer sorbed on soild, **Qs**	
	Qs= (VxCs) x (VxCf)	0.00756823
16	Calculate concentration of tracer sorbed on solid S: $S=\frac{Q_s}{M}$	0.007277144
17	Calculate distribution coefficient, **Kd** $K_d=\frac{S}{C_f}$	0.000452685
18	Additional notes:	Converted unit of V grams to L assuming 1g/ml
		concentration in g/L (Cs) From ICP MS

Row	Test ID 10	
1	Description of solid	San Joaquin Reference Soil
2	Solution ID	1
3	Species of Interest	Cs
4	Mass of Empty Bottle (g)	14.88
5	Total mass of bottle and soil (g)	14.88
6	Mass of soil (g) **M**, (Row 5 - Row 4)	0
7	Total mass of bottle, soil and solution (g)	39.9
8	Total mass of solution, **V**, (Row7-Row5) (g)	25.02
9	Experiment start time and date	12:10 pm March 1st 2019
10	Experiment end time and data	12:00 pmMarch 8th 2019
11	Filter material/Pore size	0.45
12	Starting concentration of tracer in contact solution **Cs**	
	Tests 1-3 - From solution 1	0.13550752
	Test 4-6 - From solution 2	
	Test 7-9 - From solution 3	
13	Final concentration of tracer in contact solution, **Cf**	0.13550752
	and measurment technique	ICP MS
14	Final pH of contact solution	7.33
15	Calculate quantity of tracer sorbed on soild, **Qs**	
	Qs= (VxCs) x (VxCf)	0
16	Calculate concentration of tracer sorbed on solid S: $S=\frac{Q_s}{M}$	
17	Calculate distribution coefficient, **Kd** $K_d=\frac{S}{C_f}$	
18	Additional notes:	Converted unit of V grams to L assuming 1g/ml
		concentration in g/L (Cs) From ICP MS

Row	Test ID 11	
1	Description of solid	San Joaquin Reference Soil
2	Solution ID	2
3	Species of Interest	Cs
4	Mass of Empty Bottle (g)	14.9
5	Total mass of bottle and soil (g)	14.9
6	Mass of soil (g) **M**, (Row 5 - Row 4)	0
7	Total mass of bottle, soil and solution (g)	39.92
8	Total mass of solution, **V**, (Row7-Row5) (g)	25.02
9	Experiment start time and date	12:10 pm March 1st 2019
10	Experiment end time and data	12:00 pmMarch 8th 2019
11	Filter material/Pore size	0.45
12	Starting concentration of tracer in contact solution **Cs**	
	Tests 1-3 - From solution 1	
	Test 4-6 - From solution 2	1.218616633
	Test 7-9 - From solution 3	
13	Final concentration of tracer in contact solution, **Cf**	1.218616633
	and measurment technique	ICP MS
14	Final pH of contact solution	7.67
15	Calculate quantity of tracer sorbed on soild, **Qs**	
	Qs= (VxCs) x (VxCf)	0.000929627
16	Calculate concentration of tracer sorbed on solid S: $S=\frac{Q_s}{M}$	
17	Calculate distribution coefficient, **Kd** $K_d=\frac{S}{C_f}$	
18	Additional notes:	Converted unit of V grams to L assuming 1g/ml
		concentration in g/L (Cs) From ICP MS

Row	Test ID 12	
1	Description of solid	San Joaquin Reference Soil
2	Solution ID	3
3	Species of Interest	Cs
4	Mass of Empty Bottle (g)	14.82
5	Total mass of bottle and soil (g)	14.82
6	Mass of soil (g) **M**, (Row 5 - Row 4)	0
7	Total mass of bottle, soil and solution (g)	39.82
8	Total mass of solution, **V**, (Row7-Row5) (g)	25
9	Experiment start time and date	12:10 pm March 1st 2019
10	Experiment end time and data	12:00 pmMarch 8th 2019
11	Filter material/Pore size	0.45
12	Starting concentration of tracer in contact solution **Cs**	
	Tests 1-3 - From solution 1	
	Test 4-6 - From solution 2	
	Test 7-9 - From solution 3	16.37752742
13	Final concentration of tracer in contact solution, **Cf**	16.37752742
	and measurment technique	ICP MS
14	Final pH of contact solution	8.39
15	Calculate quantity of tracer sorbed on soild, **Qs**	
	Qs= (VxCs) x (VxCf)	0.167639628
16	Calculate concentration of tracer sorbed on solid S: $S=\frac{Q_s}{M}$	
17	Calculate distribution coefficient, **Kd** $K_d=\frac{S}{C_f}$	
18	Additional notes:	Converted unit of V grams to L assuming 1g/ml
		concentration in g/L (Cs) From ICP MS

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