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Hanford Contaminant Distribution Coefficient Database and Users Guide

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G. V. Last

May 2002

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RL01830



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Summary

This document compiles in a single source the K_d values measured with Hanford sediment for radionuclides and toxic compounds that have the greatest potential for driving risk to human health and safety in the vadose zone and groundwater at the Hanford Site. A small number of available K_d values that had limited documentation and could not be readily evaluated were excluded from this compilation. In addition to the actual K_d values, all significant experimental parameters and solution and sediment characterization data associated with these K_d values have been compiled and documented as part of this task. These data will be compiled and made available on a sitewide database. This database will be periodically updated as new data become available.

In general, with proper data selection and application to appropriate conditions, the linear adsorption model (K_d model) approach is likely to be adequate for modeling transport through the Hanford system, especially for the far field where geochemical conditions remain fairly constant and contaminant loading of the adsorption sites is low. However, in some situations the linear adsorption model will not be appropriate, such as where large changes in chemical conditions occur (i.e., underneath a leaking high-level waste tank). In such cases, rapidly changing chemical conditions will result in large changes in reactivity of the contaminants with surface sites and result in large changes in K_d values. In other words, K_d values are significantly dependent on multiple chemical parameters such as pH, sodium ion concentration, or contaminant concentration. In addition, high concentrations of contaminants have the potential to saturate adsorption sites. An inherent assumption of the linear adsorption model approach is that the adsorption sites never become saturated. These limitations of the linear adsorption model approach have been dramatically illustrated by the recent work conducted on Cs(I) adsorption on Hanford sediment under conditions expected underneath a leaking high-level waste tank.

When modeling adsorption from solutions whose compositions exceed the empirical range applicable for available K_d measurements, additional measurements should be made to broaden the applicable range. In other cases, where the solution compositions and/or other adsorption parameters are not appropriate for the K_d model approach, a more sophisticated (mechanistic) adsorption model should be considered.

In order to match K_d values to a particular transport scenario, appropriate matching of solution chemistry with the chemical condition used in the K_d determinations must be made. The differences in sediment mineralogy are generally of secondary importance to differences in solution chemistry with regard to K_d values. Guidance on how to make corrections for gravel content is provided in this document. The importance of using a qualified geochemist for selecting appropriate K_d is stressed.

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1.0 Introduction

Adsorption is one of the primary mechanisms that control or retard the migration of many contaminants in the vadose zone and groundwater. The most common method used to describe contaminant adsorption on complicated matrices such as soil and sediment is the distribution coefficient or K_d model:

$$K_d = S/C_{aq} \quad (1)$$

where S = the concentration of the contaminant on the solid
 C_{aq} = the concentration in the aqueous phase.

It is generally assumed that the K_d is at equilibrium and reversible, although this is not always true. The primary drawback of this approach is that the model is empirical and should be applied only to conditions under which the K_d was measured. This condition can be relaxed if a varying parameter is known to have no or minimal influence on adsorption of the contaminant of interest. The primary advantages of this approach are that it is simple and can be applied to complex matrices and solutions for which it would be difficult or impossible to obtain all the required mechanistic surface adsorption data.

An extensive review of adsorption models is beyond the scope of this report; for detailed reviews of adsorption modeling using empirical (including the K_d model) and mechanistic approaches, see Lindsay (1979), Stumm and Morgan (1996), Langmuir (1997), and EPA (1999).

This work supports the Characterization of Systems Task of the Groundwater/Vadose Zone (GW/VZ) Integration Project. The Characterization of Systems Task is responsible for establishing a consistent set of data, parameters, and conceptual models to support efforts at the Hanford Site to estimate contaminant migration and impact (DeLamare 2000). As part of these efforts, the Characterization of Systems Task is assembling a series of catalogs and databases to identify the depth and breadth of existing data and to facilitate access to those data. It is envisioned that these catalogs and databases will continue to evolve as other existing data is found and new data collected.

This report joins four existing data catalogs that include the geologic data (Horton et al. 2001), vadose-zone hydraulic-property data (Freeman et al. 2001), surface and borehole geophysical data (Last and Horton 2000), and a catalog on release mechanisms (Riley and Lo Presti 2000). Efforts are being made to fully integrate these efforts and to facilitate the use of standardized nomenclature to which all stratigraphic, soil physics, and geochemistry data can be tied.

2.0 Purpose

The purpose of this work is to compile and thoroughly document all useful distribution coefficient data determined for Hanford sediment and related materials into one database. This report provides the

background information to access the database and provides guidance on how to properly and effectively apply the information in the database to select appropriate K_d values for numerical transport modeling efforts. A part of this work will be to identify significant data gaps and technical needs and make appropriate recommendations. The intent of this work is to maximize the value of existing K_d data, ensure consistency, and eliminate duplication of effort among various programs.

An additional purpose of this work is to increase the defensibility of the linear isotherm model that will be used in SAC Rev. 1 and other up coming performance assessments. The work will provide transport modelers guidance for selecting appropriate K_d values for various conditions that are consistent and scientifically defensible rather than excessively conservative.

3.0 Technical Need

Understanding the flux of contaminants through the vadose zone to the groundwater under varying geologic, hydrologic, and chemical conditions is key to making technically credible and sound decisions regarding soil site characterization and remediation, single-shell tank retrieval, and waste site closures (DOE 2000). One of the principal needs identified in the science and technology roadmap (DOE 2000) is the need to improve the conceptual and numerical models that describe the location of contaminants today, and to provide the basis to forecast future movement of contaminants on both site-specific and sitewide scales.

The state-of-knowledge (DOE 1999) and preliminary concepts¹ documents describe the importance of geochemical processes on the transport of contaminants through the vadose zone. These processes have been identified in the international list of Features, Events, and Processes (FEPs) and included in the list of relevant Hanford Site FEPs (Soler et al. 2001). The current vision for the Hanford sitewide cumulative risk assessment as performed using the System Assessment Capability (SAC), Rev. 0 and Rev. 1, is to represent adsorption using the linear isotherm (empirical distribution coefficient, K_d) model.

Comments from the Integration Project Expert Panel indicate that work is required to adequately justify the applicability of the linear sorption model and to identify and defend the range of K_d values that are adopted for assessments. The work plans developed for the science and technology efforts, SAC, and the core projects must answer directly the question of the scientific basis for the application of the linear sorption isotherm model to the complex waste on the Hanford Site.

The reason that well documented justification is required for using the linear sorption (K_d) model is that this approach is strictly empirical and is often applicable only under a limited range of physical-chemical conditions. As a result, K_d values can be applied with confidence only to conditions under

¹ Groundwater/Vadose Zone Integration Project, *Preliminary System Assessment Capability Concepts for Architecture, Platform and Data Management*, September 30, 1999, <http://www.bhi-erc.com/vadose/Workgrps/SAC/Report/9-30rep.pdf>

which the linear adsorption isotherm has been demonstrated to be applicable. If the sediment/soil mineralogy or physical properties, solution chemistry, or contaminant loading/concentration of the system to be modeled is significantly different than that for which the K_d values were determined, significant error in the estimated transport rates could result. This is because many factors can affect the degree to which a particular contaminant adsorbs to a particular sediment or soil. These factors include sediment mineralogy and surface area, major ion concentration (complexation and competitive adsorption), pH of the solution, and the concentration of the adsorbate in solution and on the adsorbent. Also, the application of expert geochemical knowledge can often significantly reduce the number of variables that must be considered to evaluate K_d values for each particular contaminant.

To illustrate how significant variation in K_d values can affect transport model estimates, the range of K_d values determined for the Immobilized Low-Activity Waste Performance Assessment (Kaplan and Serne 2000) will be used to calculate the variation in estimates of the retardation factor. In the first performance assessment, ^{129}I , ^{237}Np , ^{79}Se , ^{99}Tc , and $^{234/235/238}\text{U}$ were identified as radionuclides that posed the greatest potential health hazard. The estimated range of K_d values determined for these contaminants are shown in Table 1.

The retardation factor is a measure of the ratio of the average linear velocity of water divided by the average linear velocity of the contaminant. The retardation factor can be calculated using the following equation:

$$R_f = 1 + (K_d \rho_b)/\theta \quad (2)$$

where R_f = the retardation factor (unitless)
 ρ_b (kg/L) = the bulk density
 θ (L/L) = the volumetric water content.

By assuming a bulk density of 1.86 kg/L and a water content of 0.30 L/L, Equation 2 can be simplified to:

$$R_f = 1 + 6.2K_d \quad (3)$$

The retardation factors calculated from the data in Table 1 are shown in Table 2. These results illustrate the high degree of uncertainty associated with model estimates of contaminant mobility at Hanford based on available distribution coefficients. For example, the range of retardation factors for ^{129}I , ^{99}Tc , and $^{234/235/238}\text{U}$ indicate that the transport of these contaminants could vary from practically

Table 1. Range of K_d Values Determined for the Immobilized Low-Activity Waste Performance Assessment Far Field for ^{129}I , ^{237}Np , ^{79}Se , ^{99}Tc , and $^{234/235/238}\text{U}$ (Kaplan and Serne 2000)

K_d (^{129}I)	K_d (^{237}Np)	K_d (^{79}Se)	K_d (^{99}Tc)	K_d ($^{234/235/238}\text{U}$)
0.0 - 15	2 - 25	3 - 15	0.0 - 0.6	0.1 - 80

Table 2. R_f Values Calculated from the Range of K_d Values for ^{129}I , ^{237}Np , ^{79}Se , ^{99}Tc , and $^{234/235/238}\text{U}$ Estimated for the Immobilized Low-Activity Waste Performance Assessment Far Field

$R_f(^{129}\text{I})$	$R_f(^{237}\text{Np})$	$R_f(^{79}\text{Se})$	$R_f(^{99}\text{Tc})$	$R_f(^{234/235/238}\text{U})$
1 - 94	13 - 156	20 - 94	1 - 4.7	1.6 - 500

uninhibited to being significantly retarded (especially for ^{99}Tc and $^{234/235/238}\text{U}$). For ^{237}Np and ^{79}Se , the results indicate transport of these contaminants could range from moderately retarded to highly retarded.

As a result of this uncertainty, K_d values selected for modeling purposes are typically the lowest value, or close to the lowest value, of the range of values. This conservative approach is prudent in the sense that it will tend to over estimate the transport of the contaminant rather than under estimate transport. By over estimating the transport of these contaminants, overly conservative remedial actions may be selected, leading to wasted efforts and unnecessary expenditures.

In order to reduce the uncertainty in the K_d values for the contaminants of most importance, the variables that can significantly affect the K_d values should be determined and thoroughly documented. These variables will be different for different contaminants. By documenting the variables that affect important contaminant K_d values, and by combining this information with site-specific geochemical data, more precise and less conservative K_d values can be selected. In addition, data gaps can be identified that will indicate where further experimental work should be conducted to reduce the uncertainty of the current K_d value database.

4.0 Scope

The scope of this work is to provide an assessment and thorough documentation of the available contaminant distribution coefficients for Hanford sediment and related materials, and to document the conditions under which the K_d values were determined. This work will provide a mechanism to select a range of K_d values based on waste chemistry type, water geochemistry, mineralogy and, if possible, hydraulic properties that will minimize the range of uncertainty.

The scope of this work is focused on three main objectives:

- compilation/database of distribution coefficients and background characterization data for Hanford sediment with bibliography
- preparation of limited guidance for selecting distribution coefficients from the Hanford database
- identification of data gaps and needs.

4.1 Distribution Coefficient and Background Characterization Data Catalog/Database

The first effort was aimed at producing a catalog of all useful contaminant distribution coefficient data applicable to Hanford sediment and related materials. These data were evaluated and rated in terms of quality, based on how well the values are documented. Documentation included availability of the original reference, availability of sediment characterization data, solution phase characterization data, contaminant concentrations in the solution phase and solid phase, and experimental procedures used. Some older data that does not contain adequate documentation regarding the solution or sediment characteristics has been intentionally excluded from this compilation. This document also provides a comprehensive bibliography of all available published documents that contain useful distribution coefficient data applicable to the Hanford Site. The distribution coefficient and background characterization data compiled in this data catalog will be entered into an electronic database for future management and configuration control.

4.2 Guidance for Selection of Distribution Coefficients

Limited guidance to assist in the selection of distribution coefficients was developed for modelers who are not expert geochemists so that they will be able to use this information more effectively. It is highly recommended that a knowledgeable geochemist with firsthand experience in the area of contaminant adsorption, speciation chemistry, and Hanford K_d values be consulted prior to final selection of K_d values for conducting modeling efforts with critical outcomes.

4.3 Data Gaps and Needs

A logical outcome from the preparation of this document will be to identify data gaps and technical needs, and to make recommendations for resolving these needs. This will include identification of further experimental work that should be conducted to maximize the effectiveness of future transport modeling efforts.

5.0 Catalog/Database of Distribution Coefficients

This document presents distribution coefficient and background characterization data in a series of tables and appendices that are believed to represent 90% of the existing data available for the Hanford Site. The compilation of new and existing data is expected to continue and will result in updated versions of this data catalog/database.

Compilations of distribution coefficients for Am(III), Co(II), Cr(VI), Cs(I), I⁻(I), Ni(II), NO₃⁻, Np(V), Pb(II), Pu (valence unspecified), Se(VI), Sr(II), Tc(VII), U(VI), and CCl₄ are presented in Tables 3 through 17 following the main text of this report. Where applicable and available, the following information was included in the tables along with the K_d values:

- name used to identify the aqueous phase
- name used to identify the solid phase
- experimental method
- standard deviation of the K_d values (if applicable and available)
- equilibration time
- initial concentration of the adsorbate in the solution
- solution/solid ratio used in the experiment
- source reference.

In addition to these data, more detailed information regarding the composition of the solutions (aqueous phase) is given in Appendix A. More detailed information regarding the sediment composition and characteristics (solid phase) is given in Appendix B.

For the purposes of discussion, these contaminants have been grouped into three classifications:

1. contaminants with very high K_d values with very little potential for migration through the vadose zone or groundwater except under extreme conditions [Am(III), Co(II), Cs(I), Ni(II), Pb(II), and Pu]
2. contaminants with moderate K_d values with moderate potential for migration through the vadose zone or groundwater [Sr(II)]
3. contaminants with low K_d values with relatively high potential for migration through the vadose zone or groundwater [Cr(VI), I⁻(I), NO₃⁻, Np(V), Se(VI), Tc(VII), U(VI), and CCl₄].

Unless otherwise indicated, all K_d values were measured on sediment that was sieved to <2 mm (i.e., sum of sand-, silt-, and clay-size fractions). Appropriate corrections should be made when applying these values to actual field conditions with significant amounts of material >2 mm (i.e., gravel) (Kaplan et al. 2000). Note, that in some cases negative K_d values are reported. Negative K_d values are physically impossible and are the result of experimental artifacts. For modeling purposes, these values should be taken to be equal to 0.0 mL/g. The negative values are included in the table to provide a sense of the magnitude of experimental error that can occur in these numbers.

5.1 Contaminants with High K_d

Americium. K_d values for Am(III) and associated information are compiled in Table 3. Routson et al. (1975, 1976) measured Am(III) K_d values under conditions that closely approximate those of natural Hanford groundwater. These results indicate that Am(III) K_d values are high under natural conditions. Delegard and Barney (1983) measured Am(III) K_d values under highly basic pH conditions (1 M and 4 M

NaOH) with various concentrations of chelating agents. The results of this work indicate that Am(III) K_d values under highly basic conditions in the absence of ethylenediaminetetraacetic acid are also high. At these high pH values, it is not clear if the high Am(III) K_d values measured are the result of adsorption or a combination of adsorption and precipitation; it is certain that Am(III) is highly immobile under these conditions. When high concentrations of ethylenediaminetetraacetic acid are present (0.05 to 0.15 M) Am(III) K_d values are significantly reduced to low or moderate values. Am(III) K_d values measured under acidic conditions (pH<3) are low (<1 mL/g).

The general conclusions that can be drawn from these results are 1) Am(III) is generally immobile under typical groundwater pH values and above, 2) high concentrations of ethylenediaminetetraacetic acid significantly increase the mobility of Am(III), and 3) Am(III) is very mobile at pH values below 3.

Cobalt. Table 4 contains the available Co(II) K_d values applicable to Hanford conditions. Serne et al. (1993) and Gee and Campbell (1980) determined K_d values for Co(II) under natural Hanford groundwater conditions. These results indicate that under these conditions Co(II) adsorption is high. K_d values for Co(II) also were determined by Delegard and Barney (1983) under highly basic conditions (1 M and 4 M NaOH) and in the presence of various concentrations of chelating agents. These results indicate that a highly basic condition greatly reduces Co(II) (at trace concentrations) adsorption onto Hanford sediment. This is due to the formation of negatively charged hydrolysis species under strongly basic conditions. The combination of highly basic conditions and high concentrations of ethylenediaminetetraacetic acid reduces Co(II) adsorption to practically nil. Cantrell and Serne (1993) measured K_d values for Co(II) under natural Hanford groundwater conditions and with Hanford groundwater spiked with ethylenediaminetetraacetic acid and CN^- . It was determined that addition of 25 ppb ethylenediaminetetraacetic acid reduced K_d values for Co(II) from 2,500 to 1,070 mL/g. Further reductions in K_d values occurred as the ethylenediaminetetraacetic acid concentration was increased. At 200 ppb ethylenediaminetetraacetic acid, the average K_d was determined to be 71 mL/g and at 2,000 ppb, the average K_d was 3.3 mL/g. CN^- was found to reduce Co(II) adsorption even more dramatically than ethylenediaminetetraacetic acid. At 150 ppb CN^- , the average Co(II) K_d value was determined to be 1.9 mL/g and at 2,000 ppb CN^- Co(II) K_d value was reduced even further to 0.0 mL/g.

The general conclusions that can be drawn from these results are 1) Co(II) is highly immobile under normal Hanford groundwater conditions, 2) highly basic conditions dramatically reduce Co(II) adsorption, and 3) moderate to high concentrations of CN^- and high ethylenediaminetetraacetic acid concentrations greatly reduces Co(II) adsorption.

Cesium. A large body of data for Cs(I) adsorption onto Hanford sediment exists. The most useful K_d values have been compiled in Table 5. Under normal Hanford conditions, Cs(I) adsorption is high with K_d values in excess of 1,000 mL/g. Even in the presence of acidic process waste, Cs(I) adsorption remains high. This is partially due to the high acid neutralizing capacity of Hanford sediment resulting from its generally high carbonate content. The pH values measured for acidic process waste (initially pH 3.5) after contact with Hanford sediment was 4.1 to 7.5 (at solution to solid ratios of 30). Gee and Campbell (1980) demonstrated that high concentrations of K^+ can dramatically reduce Cs(I) adsorption; however, such high K^+ concentrations are not likely to occur at the Hanford Site. Serne et al. (1998) has shown that various simulated tank (T-106) waste (pH 12, with various salts at high concentration) can

significantly reduce Cs(I) adsorption. The most dramatic decrease in Cs(I) adsorption occurs when high $\text{Ca}(\text{NO}_3)_2$ (3.5 M) is included as a component of the simulated tank waste (along with relatively high concentrations of NH_4^+ and K^+). REDOX liquors that have much higher base ($\text{pH} > 14$), Al, Na, and nitrate concentrations, have been found to have higher K_d values than those of the T-106 tank waste simulants. It has been hypothesized that precipitation of high-surface-area aluminum-hydroxide phases may be responsible for this effect Serne et al. (1998). It is also likely that the much lower concentrations of Ca^{2+} , NH_4^+ , and K^+ in the REDOX liquors were also very important factors.

Zachara et al. (2002) have presented a detailed mass action ion exchange model for Cs(I) adsorption onto Hanford sediment. This model is sensitive to the concentration of Cs(I) in the system because of selective adsorption sites (frayed edge sites on mica minerals) that are present in low concentrations that control Cs(I) adsorption at low aqueous Cs(I) concentrations. In addition, high salt concentrations that exist in tank waste greatly reduces Cs(I) adsorption. As a result of this work, it is clear that modeling Cs(I) adsorption in the vicinity of a tank leak will not be amenable to modeling with a single linear adsorption isotherm.

In summary, it appears that Cs(I) transport through the Hanford Site vadose zone and groundwater will be negligible except under conditions of extremely high salt concentration [Ca^{2+} , NH_4^+ , and K^+ are particularly good competitors for adsorption sites with Cs(I)].

Nickel. Ni(II) K_d values compiled for this database are shown in Table 6. Adsorption of Ni(II) onto Hanford sediment is high but somewhat less than that of Co(II). Ni(II) adsorption data are available as a function of contact time and initial concentration of Ni(II). K_d values for the radionuclides previously discussed were all conducted at trace concentrations. Increasing the equilibration time results in significant increases in the measured K_d values. In addition, increasing the concentration of Ni(II) initially added to solution significantly reduces the measured K_d values. The highest Ni(II) concentrations used in these experiments are near the solubility limits expected in Hanford groundwater (Rhodes et al. 1994).

It is apparent, from the available results for Ni(II) adsorption onto Hanford sediment under normal groundwater conditions, that the mobility of nickel is limited. Even at the highest nickel concentrations studied (5×10^{-5} M), a retardation factor in excess of 300 can be expected. As the Ni(II) concentrations decrease and the contact time increases, retardation factors in excess of 4,000 are expected.

Lead. Pb(II) K_d values determined with Hanford sediment are presented in Table 7. Pb(II) adsorption onto Hanford sediment also is high, even higher than that of Co(II). As is the case for Ni(II), K_d values for Pb(II) are available as a function of time and initial concentration of Ni(II). In a similar fashion to that observed for Ni(II), K_d values for Pb(II) are observed to increase with increasing equilibration times and decreasing initial Pb(II) solution concentrations. Because the solubility limit for Pb(II) in Hanford Site groundwater is significantly less than for Ni(II) (Rhoads et al. 1992), the maximum possible solution concentration for Pb(II) is much lower than that of Ni(II), as a result, the degree of site loading is significantly lower for Pb(II) than for Ni(II). These results show that under normal conditions Pb(II) is extremely immobile in the Hanford vadose zone and groundwater.

Plutonium. Available K_d values for Pu were measured on Hanford sediment have been compiled in Table 8. The quantity and quality of Pu adsorption studies conducted with Hanford sediment are much less than those available for many other contaminants of interest at the Hanford Site. Delegard and Barney (1983) conducted a series of Pu adsorption experiments on Hanford sediment at high base concentrations and variable concentrations of chelating agents. From their results, it was demonstrated that even at high base concentrations Pu adsorption was moderately high. Combination of high base concentration and high ethylenediaminetetraacetic acid concentration reduced Pu adsorption the most; however, even under these conditions significant adsorption occurred. Hajek and Knoll (1966) conducted Pu adsorption experiments on Hanford sediment from high salt acid waste. Under these conditions, the K_d values for Pu were determined to be less than 1. In another study conducted by Rhodes (1952, 1957), K_d values for Pu were measured on Hanford sediment at different solution to solid ratios, variable initial Pu concentrations and a range of pH values from 0.5 to 14. In general, these results indicate high Pu adsorption, except at very low pH. The results of Rhodes at low and high pH are not consistent with the previous results discussed. It is possible that the high K_d values determined by Rhodes resulted from precipitation as a result of the high initial Pu [stated to be Pu(IV)] concentrations used in the experiments.

Based on the limited data available for Pu, it appears that Pu will be fairly immobile except at very low pH values or high ethylenediaminetetraacetic acid concentrations.

5.2 Contaminants with Moderate K_d

Strontium. As was the case for Cs(I), a large number of studies of Sr(II) adsorption on Hanford sediment have been conducted. The K_d values determined in these studies are listed in Table 9. Under most natural conditions, Sr(II) adsorption onto Hanford sediment is moderate with K_d values that range from approximately 10 to 20, although much higher values have been measured in fine-grained material, presumably due to the much higher clay content in these materials (Serne and LeGore 1996). Acidic conditions and high salt concentrations (calcium, magnesium, ammonium, and potassium in particular) can significantly reduce Sr(II) adsorption onto Hanford sediment. High concentrations of ethylenediaminetetraacetic acid can reduce Sr(II) adsorption to essentially zero. High pH conditions in the absence of high concentrations of competitive cations and ethylenediaminetetraacetic acid increases Sr(II) adsorption. In addition to greater adsorption, the higher K_d values determined for Sr(II) at high pH may reflect some co-precipitation of Sr(II) into calcium/magnesium carbonates that could precipitate from groundwater as the pH is increased. It appears that under most circumstances strontium migration in Hanford sediment will be fairly limited.

5.3 Contaminants with Low K_d

Chromium. Cr(VI) K_d values determined with Hanford sediment are presented in Table 10. Only a few studies of Cr(VI) adsorption on Hanford soil are available. These results indicate that under normal Hanford Site groundwater conditions, Cr(VI) adsorption is very low. Measured K_d values range from 0 to 1, with typical values being zero or close to zero. Under acidic conditions, adsorption of this anionic species becomes significant. This increase in adsorption with decreasing pH is expected for anions due to the increase in the number of positive surface sites on the sediment with decreasing pH. An interesting observation with regard to Cr(VI) adsorption to Hanford sediment under acidic conditions, is that K_d

values show a significant increase with increasing equilibration time. It is speculated that this may be caused by slow release of ferrous iron from basalt in the Hanford sediment. The ferrous iron leached from the sediment can act as a reductant for Cr(VI). Reduction of Cr(VI) to Cr³⁺ would result in precipitation of Cr(OH)₃(s) and result in the apparently high K_d values. Except under acidic conditions adsorption of Cr(VI) is low to non-existent.

Iodine. Table 11 is a tabulation of K_d values determined for I(I) adsorption onto Hanford sediment. Iodide [I(I)] is expected to be the dominant species of iodine in Hanford groundwater (Kaplan and Serne 2000). I(I) adsorption experiments generally indicate relatively low adsorption. Under typical Hanford Site groundwater conditions, K_d values range from approximately 0 to 2 mL/g with a range of 0 to 0.2 mL/g being most typical. Consistent with anionic adsorption in general, acidic conditions appear to increase I(I) adsorption; however, sufficient data are not available to make a firm conclusion. Note that in most Hanford geochemical environments the pH does not drop below 7 because of the ubiquitous occurrence of carbonates in Hanford sediment and the preponderance of alkaline waste discharges. Also, long equilibration periods (>100 days) result in a non-linear increase in K_d values with time. The reason for this is unclear, but it is speculated that microbial activity may have played a significant role in this phenomenon. The formation of microbial colonies has been observed in a number of similar long-term adsorption experiments. These conditions are not expected to be typical of Hanford Site groundwater conditions, and it is recommended that these high values be ignored for typical transport modeling exercises.

Nitrate. The limited number of K_d values determined for NO₃⁻ using Hanford sediment are shown in Table 12. Only one study is available in which nitrate adsorption was measured. These results indicate that nitrate adsorption is essentially zero (within experimental error).

Neptunium. K_d values for Np(V) determined using Hanford sediment are compiled in Table 13. These data indicate Np(V) adsorption is generally moderate, with K_d values in the general range of 2 to 30 mL/g. Lower values can result at contact times of 1 day or less and high calcium or ethylenediamine-tetraacetic acid concentrations in solution. High solution pH values can result in much higher K_d values. These results indicate that Np(V) from a tank leak should be minimal unless high ethylenediamine-tetraacetic acid concentrations occur. Moderate migration of Np(V) could occur in the vadose zone and groundwater under natural Hanford conditions.

Selenium. A fair number of Se(VI) K_d values have been determined using natural Hanford sediment and are listed in Table 14. These results indicate that at trace concentrations, adsorption of Se(VI) to Hanford sediment is low to moderate with K_d values ranging from 3 to 10 mL/g. At higher Se(VI) concentrations, the K_d values are lower (0 to 3 mL/g). Acidic conditions increase Se(VI) adsorption, and basic conditions reduce adsorption. This is consistent with the anionic character of Se(VI).

Technetium. Tc(VII) K_d values measured on Hanford sediment are shown in Table 15. Tc(VII) adsorption is low under nearly all conditions relevant to the Hanford vadose zone and upper unconfined aquifer, with K_d values ranging from zero to a high of approximately 1 mL/g; however, these high values also have high standard deviations. In one study, K_d values approaching 1 mL/g appeared to be most

representative; however, this was not substantiated by any other studies. Under normal Hanford conditions, zero appears to be the most appropriate value, with a best estimate for the range as 0.0 to 0.1 mL/g.

Uranium. Table 16 contains K_d values determined for U(VI) adsorption on Hanford sediment. Under natural Hanford groundwater conditions, U(VI) adsorption is moderate with K_d values ranging from approximately 0.2 to 4. Much higher K_d values have been reported (Serne et al. 1993) but these values appear to be suspect. In the case of the TBS-1 results determined in Hanford groundwater, nothing is unusual about the sediment or groundwater. In the cases in which U(VI) adsorption was measured from acid process waste, adsorption should actually be lower as a result of the lower equilibrium pH values reached in these experiments. However, the reported adsorption from the acid process waste is much higher than observed in any other studies. For example, the maximum U(VI) adsorption onto natural sediment from natural groundwater indicate that an adsorption maximum occurs in the pH range of approximately 6 to 8, with lower adsorption occurring at a lower pH due to protonation of the adsorption sites and a shift to more positively charged uranyl species in solution (Payne and White 1991; Davis 2001). Lower adsorption also occurs at higher pH values due to formation of more negatively charged uranyl-carbonate species and deprotonation of the surface sites. These previously reported high K_d values for uranium have had a significant effect on recommended K_d values. For example, the recommended range suggested in the Immobilized Low-Activity Waste Performance Assessment Far Field for $^{234/235/238}\text{U}$ is 0.1 to 80 (Kaplan and Serne 2000). Based on this analysis, a range of 0.2 to 4 is more likely to be appropriate. Uranium migration under natural Hanford conditions will be high to moderate with greater migration occurring at high and low pH values.

Carbon Tetrachloride. The only K_d values available for Hanford sediment were measured by the author (unpublished data). The sediment used for these measurements were collected on November 5, 1991, from well 299-W11-27 at a depth of 200 feet. The measurements were made by adding 40 mls of Hanford groundwater (well 6-S3-25) spiked with carbon tetrachloride at concentrations ranging from 5 to 10,000 ppb to 1 gram of sediment (<2 mm) in glass vials with teflon sealing caps and equilibrating for several days. The mean and standard deviation for the measured K_d values was -0.8 ± 0.8 mL/g. The reason for the negative values is an artifact of the K_d determination method (Relyea et al. 1980), in which equilibrium concentration values are subtracted from blank concentrations. Because carbon tetrachloride is so volatile any small losses from the blanks that are higher than the sample values will result in a negative K_d value. As a result, it is assumed that the actual K_d value for Hanford sediment is 0.0 ± 0.8 mL/g.

Others (Truex et al. 2001) have used estimation methods based on the fraction of organic carbon in the soil and the water solubility of the compound of interest to estimate K_d values for organic contaminants for Hanford sediment. However, these estimation methods are known to underestimate K_d values for organic carbon concentrations below approximately 0.1%. The average organic content for Hanford sediment is typically 0.03%. As a result, these estimation methods are not generally useful for Hanford sediment.

A more reliable method to estimate carbon tetrachloride K_d values for Hanford sediment is to compare with values measured on sediment that has low organic contents similar to that of Hanford

sediment. This is reasonable because mineralogical differences do not have a significant impact on the adsorption of hydrophobic contaminants. Particle size range (surface area) will have a much more significant impact than mineralogy.

Brusseau et al. (1991) measured retardation factors for carbon tetrachloride in an aquifer material that was greater than 98% sand (Rabis baek). The fraction of organic carbon for this material was 0.00007. Using the given bulk density and pore water content, a K_d of 0.25 mL/g was calculated (for 10°C). A series of field and laboratory investigations were conducted at a site in Borden, Ontario, to evaluate the transport of a halogenated hydrocarbon compounds (Makay et al. 1986; Roberts et al. 1986; Curtis et al. 1986). The Borden aquifer material is a clean, well-sorted, fine-to-medium grained sand with an average organic carbon fraction of 0.0002 (range 0.0001 to 0.0009) (Mackay et al. 1986). Batch experiments conducted at 21°C resulted in a K_d of 0.15 mL/g. After correcting for differences in temperature, retardation factors calculated with this K_d value were in very good agreement with retardation factors determined from both temporal and spatial field data. Chin et al. (1988) measured a K_d value for a soil collected from Michawye Michigan. This soil had a sandy character and a fractional organic carbon content of 0.0013. The K_d value was determined to be 0.542 mL/g (presumably at room temperature).

Based on the data presented here, it is estimated that the most probable value for a K_d for carbon tetrachloride adsorption onto Hanford sediment is 0.2 mL/g, with a range of approximately 0.1 to 0.6.

5.4 Suspended Sediment K_d Values

In addition to K_d values for groundwater and the vadose zone, K_d values also are needed for Columbia River suspended sediment. At this time, no measurements of K_d values for Columbia River suspended sediment are available. The suspended sediment will be significantly different than typical Hanford sediment. The suspended sediment will consist primarily of silt and clay size material and have a significantly higher organic carbon content. Due to the lack of measured suspended sediment K_d values, an estimation technique was used. The low, median and upper limit suspended sediment K_d values for I(I), U(VI), Sr(II), Cs(I), Pu (valence unspecified), were estimated to be 1, 10, and 100x the values determined for Hanford sediment/groundwater. The mean K_d values determined for Cr(VI), and Tc(VII) for Hanford sediment/groundwater are zero, therefore the suspended sediment K_d values were estimated as 1, 10, and 100x the maximum K_d values determined for Hanford sediment/groundwater. For carbon tetrachloride, the median K_d value was estimated using Equation 4:

$$K_d = f_{oc} \times K_{oc} \quad (4)$$

where f_{oc} = the mass fraction organic matter
 K_{oc} = the distribution coefficient for organic carbon.

K_{oc} was assumed to be 136 mL/g (the average from Table 1, Truex et al. 2001) and f_{oc} was assumed to be 0.01. Using these values, the median suspended sediment K_d value for carbon tetrachloride was estimated to be 1.4 mL/g. The minimum values are assumed to be 0.14 g/ml and the maximum is assumed to be 2.8 mL/g.

6.0 Guidance for Selecting K_d Values from K_d Database

In order to select a K_d value that is sufficiently accurate for transport modeling purposes, careful consideration must be given to the K_d values available for Hanford sediment listed in Tables 3 through 17 and the corresponding conditions under which these values were determined (Appendices A and B). The specific set of conditions for which a particular K_d value is to be applied should be matched as closely as possible to the experimental conditions used for determining the selected K_d value. In general (for most <2 mm Hanford formation sediment), differences in the chemical properties of the solution influence the K_d values to a much greater extent than do differences in sediment properties. In addition, fewer data have been collected that are suitable for evaluating differences in K_d values among different geologic units at Hanford (e.g., Hanford, Plio-Pleistocene, Ringold). As a result, more effort should be focused on the evaluation of the impact of solution chemical factors when selecting K_d values. When attempting to select an appropriate K_d value, greater reliability should be placed on values that have been measured multiple times, preferably in separate studies. In some cases, suspect outliers should be excluded from consideration, as was done in the case of uranium in this report.

Because different chemical parameters will affect the adsorption properties of individual contaminants differently; it is important that an individual with expert geochemical knowledge and experience in working with and determining K_d values be used to evaluate and select appropriate K_d values for transport modeling. Because K_d values are available for only a limited set of conditions, a certain amount of interpolation and extrapolation may be required to select K_d values for all conditions required for the transport models.

K_d measurements are generally conducted on Hanford sediment material that is <2 mm in size. For materials that contain significant amounts of gravel, K_d values will be lower than those determined with <2 mm size material because the surface area and corresponding quantity of adsorption sites is much lower. For high gravel content material, often present at Hanford, especially near the Columbia River, it is necessary to make corrections to K_d values determined with <2 mm size material. For high K_d contaminants (Cs, Sr, and Pu), Equation 5 is recommended (see Appendix A, Kaplan and Serne 2000).

$$K_{d_{gc}} = (1-f) K_{d_{<2mm}} + (f)0.23 K_{d_{<2mm}} \quad (5)$$

where $K_{d_{gc}}$ = the gravel corrected K_d value
f = the weight fraction gravel
 $K_{d_{<2mm}}$ = the K_d value determined using <2 mm material.

For low K_d contaminants, the following equation is recommended

$$K_{d_{gc}} = (1-f) K_{d_{<2mm}} \quad (6)$$

7.0 Data Gaps, Technical Needs, and Recommendations

In general, the amount of error associated with a particular K_d value (on a percentage basis) that is acceptable increases as the K_d value increases. This is because contaminants with low K_d values are the most mobile and as a result are more likely to be associated with greater risk. Large errors associated with high K_d values will make a smaller difference from a risk perspective because the contaminant is not very mobile anyway, whereas large variations associated with moderate or low K_d values can make the difference between whether the contaminant will be a significant risk driver or not.

Based on this rationale, the most beneficial future enhancements to the K_d database would be obtained by focusing on the contaminants with low K_d values [Cr(VI), I(I), NO_3^- , Np(V), Se(VI), Tc(VII), and U(VI)]. This list can be reduced further with other considerations, such as need, relative quality and quantity of available data, and other risk factors such as drinking water standards and quantity of the contaminants released at Hanford. Based upon the available data, it appears that the greatest need for further K_d value determinations are for these low K_d contaminants under the combined conditions of high pH and high salt. Also, consideration should be given to designing the experiments to reduce standard error as much as practical. A second data gap is the lack of K_d values for sediment from the deeper unsaturated and saturated zones within the Plio-Pleistocene and Ringold Formations. Data for contaminant waste solution types is almost non-existent for these sediment types. No measured K_d values are available for Columbia River suspended sediment. The range of the estimated K_d values for suspended sediment could be greatly reduced by conducting measurements with actual material.

8.0 Discussion

A large body of K_d data has been collected for radionuclides and toxic compounds that have the greatest potential for driving risk to human health and safety in the vadose zone and groundwater at the Hanford Site. In addition to the actual K_d values, all significant experimental parameters and solution and sediment characterization data associated with these K_d values have been compiled and documented as part of this task.

In general, with proper data selection and application to appropriate conditions, the linear adsorption model (K_d model) approach will be adequate for modeling transport through the Hanford system, especially for the far field where geochemical conditions remain fairly constant and contaminant loading of the adsorption sites is low. However, in some situations such as where large changes in chemical conditions occur (underneath a leaking high-level waste tank for example), the linear adsorption model will not be appropriate. In such cases, rapidly changing chemical conditions will result in large changes in reactivity of the contaminants with surface sites and result in large changes in K_d values. In other words, K_d values are significantly dependent on multiple chemical parameters such as pH, sodium ion concentration, or contaminant concentration. High concentrations of contaminants have the potential to

saturate adsorptions sites. An inherent assumption of the linear adsorption model approach is that the adsorption sites never become saturated. These limitations of the linear adsorption model approach have been dramatically illustrated by the recent work conducted on Cs(I) adsorption on Hanford sediment under conditions expected underneath a leaking high-level waste tank (Zachara et al. 2002).

When modeling adsorption from solutions whose compositions exceed the empirical range applicable for available K_d measurements, additional measurements should be made to broaden the applicable range. In other cases, where the solution compositions and/or other adsorption parameters are not appropriate for the K_d model approach, a more sophisticated (mechanistic) adsorption model should be considered.

Future revisions to this document/database are anticipated as new data become available. General guidance was provided to assist in the selection of appropriate K_d values. This included appropriate matching of solution chemistry with the chemical condition used in the K_d determinations. The effect of the differences in sediment mineralogy was indicated to be secondary to differences in solution chemistry with regard to impact of K_d values. Guidance on how to make corrections for gravel content was also provided. The importance of using a qualified geochemist for selecting appropriate K_d was stressed.

Table 3. Contaminant Distribution Coefficient Data for Americium

Species	Aqueous Phase	Solid Phase	Method	K_d (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/Solid (mL/g)	Reference
Am(III)	0.002 M $\text{Ca}(\text{NO}_3)_2$	Burbank Sand	Batch	>1200		1 day	Trace	2.5	(a,b)
Am(III)	0.02 M $\text{Ca}(\text{NO}_3)_2$	Burbank Sand	Batch	>1200		1 day	Trace	2.5	(a,b)
Am(III)	0.05 M $\text{Ca}(\text{NO}_3)_2$	Burbank Sand	Batch	>1200		1 day	Trace	2.5	(a,b)
Am(III)	0.10 M $\text{Ca}(\text{NO}_3)_2$	Burbank Sand	Batch	>1200		1 day	Trace	2.5	(a,b)
Am(III)	0.20 M $\text{Ca}(\text{NO}_3)_2$	Burbank Sand	Batch	>1200		1 day	Trace	2.5	(a,b)
Am(III)	Soln 1	Sed L	Batch	4.02		7 days	Trace	5	(c)
Am(III)	Soln 2	Sed L	Batch	2.85		7 days	Trace	5	(c)
Am(III)	Soln 3	Sed L	Batch	148		7 days	Trace	5	(c)
Am(III)	Soln 4	Sed L	Batch	7.79		7 days	Trace	5	(c)
Am(III)	Soln 5	Sed L	Batch	>153		7 days	Trace	5	(c)
Am(III)	Soln 6	Sed L	Batch	>1080		7 days	Trace	5	(c)
Am(III)	Soln 7	Sed L	Batch	337		7 days	Trace	5	(c)
Am(III)	Soln 8	Sed L	Batch	99.6		7 days	Trace	5	(c)
Am(III)	Soln 9	Sed L	Batch	1.11		7 days	Trace	5	(c)
Am(III)	Soln 10	Sed L	Batch	3.25		7 days	Trace	5	(c)
Am(III)	Soln 11	Sed L	Batch	15.93		7 days	Trace	5	(c)
Am(III)	Soln 12	Sed L	Batch	6.87		7 days	Trace	5	(c)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Am(III)	Soln 13	Sed L	Batch	3.22		7 days	Trace	5	(c)
Am(III)	Soln 14	Sed L	Batch	>1730		7 days	Trace	5	(c)
Am(III)	Soln 15	Sed L	Batch	48.6		7 days	Trace	5	(c)
Am(III)	Soln 16	Sed L	Batch	3.43		7 days	Trace	5	(c)
Am(III)	Soln 17	Sed L	Batch	2.03		7 days	Trace	5	(c)
Am(III)	Soln 18	Sed L	Batch	2.95		7 days	Trace	5	(c)
Am(III)	Soln 19	Sed L	Batch	9.52		7 days	Trace	5	(c)
Am(III)	Soln 20	Sed L	Batch	>470		7 days	Trace	5	(c)
Am(III)	Soln 1	Sed P	Batch	4.4		7 days	Trace	5	(c)
Am(III)	Soln 2	Sed P	Batch	2.2		7 days	Trace	5	(c)
Am(III)	Soln 3	Sed P	Batch	119		7 days	Trace	5	(c)
Am(III)	Soln 4	Sed P	Batch	6.68		7 days	Trace	5	(c)
Am(III)	Soln 5	Sed P	Batch	>169		7 days	Trace	5	(c)
Am(III)	Soln 6	Sed P	Batch	>1670		7 days	Trace	5	(c)
Am(III)	Soln 7	Sed P	Batch	288		7 days	Trace	5	(c)
Am(III)	Soln 8	Sed P	Batch	66.2		7 days	Trace	5	(c)
Am(III)	Soln 9	Sed P	Batch	0.97		7 days	Trace	5	(c)
Am(III)	Soln 10	Sed P	Batch	4.25		7 days	Trace	5	(c)
Am(III)	Soln 11	Sed P	Batch	10.1		7 days	Trace	5	(c)
Am(III)	Soln 12	Sed P	Batch	5.99		7 days	Trace	5	(c)
Am(III)	Soln 13	Sed P	Batch	2.43		7 days	Trace	5	(c)
Am(III)	Soln 14	Sed P	Batch	306		7 days	Trace	5	(c)
Am(III)	Soln 15	Sed P	Batch	41		7 days	Trace	5	(c)
Am(III)	Soln 16	Sed P	Batch	4.13		7 days	Trace	5	(c)
Am(III)	Soln 17	Sed P	Batch	2.01		7 days	Trace	5	(c)
Am(III)	Soln 18	Sed P	Batch	2.76		7 days	Trace	5	(c)
Am(III)	Soln 19	Sed P	Batch	7.5		7 days	Trace	5	(c)
Am(III)	Soln 20	Sed P	Batch	>520		7 days	Trace	5	(c)
Am(III)	Soln 1	Sed S	Batch	28.6		7 days	Trace	5	(c)
Am(III)	Soln 2	Sed S	Batch	5.91		7 days	Trace	5	(c)
Am(III)	Soln 3	Sed S	Batch	>3160		7 days	Trace	5	(c)
Am(III)	Soln 4	Sed S	Batch	28.5		7 days	Trace	5	(c)
Am(III)	Soln 5	Sed S	Batch	>133		7 days	Trace	5	(c)
Am(III)	Soln 6	Sed S	Batch	>1300		7 days	Trace	5	(c)
Am(III)	Soln 7	Sed S	Batch	439		7 days	Trace	5	(c)
Am(III)	Soln 8	Sed S	Batch	380		7 days	Trace	5	(c)
Am(III)	Soln 9	Sed S	Batch	2.47		7 days	Trace	5	(c)
Am(III)	Soln 10	Sed S	Batch	10.8		7 days	Trace	5	(c)
Am(III)	Soln 11	Sed S	Batch	72		7 days	Trace	5	(c)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Am(III)	Soln 12	Sed S	Batch	12		7 days	Trace	5	(c)
Am(III)	Soln 13	Sed S	Batch	5.7		7 days	Trace	5	(c)
Am(III)	Soln 14	Sed S	Batch	>2350		7 days	Trace	5	(c)
Am(III)	Soln 15	Sed S	Batch	187		7 days	Trace	5	(c)
Am(III)	Soln 16	Sed S	Batch	10.4		7 days	Trace	5	(c)
Am(III)	Soln 17	Sed S	Batch	4.68		7 days	Trace	5	(c)
Am(III)	Soln 18	Sed S	Batch	9.45		7 days	Trace	5	(c)
Am(III)	Soln 19	Sed S	Batch	24.6		7 days	Trace	5	(c)
Am(III)	Soln 20	Sed S	Batch	>481		7 days	Trace	5	(c)
Am(III)	AAW, pH 1.7*	299-W18-6, -7	Batch	<1					(d)
Am(III)	AAW, pH 2	299-W18-6, -7	Batch	<1					(d)
Am(III)	AAW, pH 3	299-W18-6, -7	Batch	<1					(d)
(a) Rouston et al. 1975. (b) Rouston et al. 1976. (c) Delegard and Barney 1983. (d) Hajek and Knoll 1966. *Data is best estimate.									

Table 4. Contaminant Distribution Coefficient Data for Cobalt

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Soln/Solid (mL/g)	Reference
Co(II)	Hanford GW	Trench-8	Batch	1.25E+04	6.00E+02	5 days	Trace	30	(a)
Co(II)	Hanford GW	Trench-8	Batch	1.16E+04	6.00E+02	44 days	Trace	30	(a)
Co(II)	Solution 1	Soil B	Batch	4570	650	7 days	Trace	30	(b)
Co(II)	Solution 2	Soil B	Batch	2750	200	7 days	Trace	30	(b)
Co(II)	Solution 3	Soil B	Batch	3670	160	7 days	Trace	30	(b)
Co(II)	Solution 4	Soil B	Batch	11070	6480	7 days	Trace	30	(b)
Co(II)	Solution 5	Soil B	Batch	2735	490	7 days	Trace	30	(b)
Co(II)	Solution 6	Soil B	Batch	4090	620	7 days	Trace	30	(b)
Co(II)	Soln 1	Sed L	Batch	-0.35		7 days	Trace	5	(c)
Co(II)	Soln 2	Sed L	Batch	-0.02		7 days	Trace	5	(c)
Co(II)	Soln 3	Sed L	Batch	20.4		7 days	Trace	5	(c)
Co(II)	Soln 4	Sed L	Batch	0.404		7 days	Trace	5	(c)
Co(II)	Soln 5	Sed L	Batch	3.13		7 days	Trace	5	(c)
Co(II)	Soln 6	Sed L	Batch	0.927		7 days	Trace	5	(c)
Co(II)	Soln 7	Sed L	Batch	1.96		7 days	Trace	5	(c)
Co(II)	Soln 8	Sed L	Batch	5.79		7 days	Trace	5	(c)
Co(II)	Soln 9	Sed L	Batch	0.257		7 days	Trace	5	(c)
Co(II)	Soln 10	Sed L	Batch	0.248		7 days	Trace	5	(c)
Co(II)	Soln 11	Sed L	Batch	-0.078		7 days	Trace	5	(c)
Co(II)	Soln 12	Sed L	Batch	-0.169		7 days	Trace	5	(c)
Co(II)	Soln 13	Sed L	Batch	-0.168		7 days	Trace	5	(c)
Co(II)	Soln 14	Sed L	Batch	2.97		7 days	Trace	5	(c)
Co(II)	Soln 15	Sed L	Batch	23.4		7 days	Trace	5	(c)
Co(II)	Soln 16	Sed L	Batch	0.382		7 days	Trace	5	(c)
Co(II)	Soln 17	Sed L	Batch	0.116		7 days	Trace	5	(c)
Co(II)	Soln 18	Sed L	Batch	1.45		7 days	Trace	5	(c)
Co(II)	Soln 19	Sed L	Batch	0.251		7 days	Trace	5	(c)
Co(II)	Soln 20	Sed L	Batch	1.1		7 days	Trace	5	(c)
Co(II)	Soln 1	Sed P	Batch	-0.391		7 days	Trace	5	(c)
Co(II)	Soln 2	Sed P	Batch	-0.409		7 days	Trace	5	(c)
Co(II)	Soln 3	Sed P	Batch	16.7		7 days	Trace	5	(c)
Co(II)	Soln 4	Sed P	Batch	0.782		7 days	Trace	5	(c)
Co(II)	Soln 5	Sed P	Batch	3.71		7 days	Trace	5	(c)
Co(II)	Soln 6	Sed P	Batch	1.44		7 days	Trace	5	(c)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Soln/Solid (mL/g)	Reference
Co(II)	Soln 7	Sed P	Batch	2.02		7 days	Trace	5	(c)
Co(II)	Soln 8	Sed P	Batch	4.54		7 days	Trace	5	(c)
Co(II)	Soln 9	Sed P	Batch	0.122		7 days	Trace	5	(c)
Co(II)	Soln 10	Sed P	Batch	0.298		7 days	Trace	5	(c)
Co(II)	Soln 11	Sed P	Batch	0.139		7 days	Trace	5	(c)
Co(II)	Soln 12	Sed P	Batch	-0.21		7 days	Trace	5	(c)
Co(II)	Soln 13	Sed P	Batch	-0.049		7 days	Trace	5	(c)
Co(II)	Soln 14	Sed P	Batch	2.58		7 days	Trace	5	(c)
Co(II)	Soln 15	Sed P	Batch	21.9		7 days	Trace	5	(c)
Co(II)	Soln 16	Sed P	Batch	0.574		7 days	Table	5	(c)
Co(II)	Soln 17	Sed P	Batch	0.183		7 days	Trace	5	(c)
Co(II)	Soln 18	Sed P	Batch	1.68		7 days	Trace	5	(c)
Co(II)	Soln 19	Sed P	Batch	-0.033		7 days	Trace	5	(c)
Co(II)	Soln 20	Sed P	Batch	0.915		7 days	Trace	5	(c)
Co(II)	Soln 1	Sed S	Batch	-0.057		7 days	Trace	5	(c)
Co(II)	Soln 2	Sed S	Batch	0.095		7 days	Trace	5	(c)
Co(II)	Soln 3	Sed S	Batch	14.8		7 days	Trace	5	(c)
Co(II)	Soln 4	Sed S	Batch	1.21		7 days	Trace	5	(c)
Co(II)	Soln 5	Sed S	Batch	2.41		7 days	Trace	5	(c)
Co(II)	Soln 6	Sed S	Batch	0.786		7 days	Trace	5	(c)
Co(II)	Soln 7	Sed S	Batch	1.95		7 days	Trace	5	(c)
Co(II)	Soln 8	Sed S	Batch	3.77		7 days	Trace	5	(c)
Co(II)	Soln 9	Sed S	Batch	0.121		7 days	Trace	5	(c)
Co(II)	Soln 10	Sed S	Batch	-0.036		7 days	Trace	5	(c)
Co(II)	Soln 11	Sed S	Batch	0.366		7 days	Trace	5	(c)
Co(II)	Soln 12	Sed S	Batch	-0.053		7 days	Trace	5	(c)
Co(II)	Soln 13	Sed S	Batch	-0.025		7 days	Trace	5	(c)
Co(II)	Soln 14	Sed S	Batch	2.84		7 days	Trace	5	(c)
Co(II)	Soln 15	Sed S	Batch	13.3		7 days	Trace	5	(c)
Co(II)	Soln 16	Sed S	Batch	0.572		7 days	Trace	5	(c)
Co(II)	Soln 17	Sed S	Batch	0.102		7 days	Trace	5	(c)
Co(II)	Soln 18	Sed S	Batch	0.723		7 days	Trace	5	(c)
Co(II)	Soln 19	Sed S	Batch	-0.079		7 days	Trace	5	(c)
Co(II)	Soln 20	Sed S	Batch	1.22		7 days	Trace	5	(c)
Co(II)	HGW3	200-BP-1	Batch	2556	209	14 days	Trace	30	(d)
Co(II)	150 ppb CN	200-BP-1	Batch	1.9	0.2	14 days	Trace	30	(d)
Co(II)	2000 ppb CN	200-BP-1	Batch	0.03	0.06	14 days	Trace	30	(d)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Soln/Solid (mL/g)	Reference
Co(II)	25 ppb EDTA	200-BP-1	Batch	1071	138	14 days	Trace	30	(d)
Co(II)	200 ppb EDTA	200-BP-1	Batch	72	7	14 days	Trace	30	(d)
Co(II)	2000 ppb EDTA	200-BP-1	Batch	3	1	14 days	Trace	30	(d)
(a) Serne et al. 1993. (b) Gee and Campbell 1980. (c) Delegard and Barney 1983. (d) Cantrell and Serne 1993.									

Table 5. Contaminant Distribution Coefficient Data for Cesium

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Cs(I)	Hanford GW	CGS-1	Batch	1270	36	4 days	Trace	30	(a)
Cs(I)	Hanford GW	CGS-1	Batch	2190	414	14 days	Trace	30	(a)
Cs(I)	Hanford GW	CGS-1	Batch	3120	630	35 days	Trace	30	(a)
Cs(I)	Acid Proc Waste	CGS-1	Batch	1630	310	4 days	Trace	30	(a)
Cs(I)	Acid Proc Waste	CGS-1	Batch	3120	520	14 days	Trace	30	(a)
Cs(I)	Acid Proc Waste	CGS-1	Batch	3580	904	35 days	Trace	30	(a)
								30	(a)
Cs(I)	Hanford GW	TBS-1	Batch	3720	760	4 days	Trace	30	(a)
Cs(I)	Hanford GW	TBS-1	Batch	5110	690	14 days	Trace	30	(a)
Cs(I)	Hanford GW	TBS-1	Batch	14000	1630	35 days	Trace	30	(a)
Cs(I)	Acid Proc Waste	TBS-1	Batch	2330	420	4 days	Trace	30	(a)
Cs(I)	Acid Proc Waste	TBS-1	Batch	3380	270	14 days	Trace	30	(a)
Cs(I)	Acid Proc Waste	TBS-1	Batch	3180	130	35 days	Trace	30	(a)
Cs(I)	Hanford GW	Trench-8	Batch	540	30	5 days	Trace	30	(a)
Cs(I)	Hanford GW	Trench-8	Batch	690	80	44 days	Trace	30	(a)
Cs(I)	Solution 1	Soil A	Batch	5307	100	8.5 days	Trace	30	(b)
Cs(I)	Solution 2	Soil A	Batch	3377	1311	8.5 days	Trace	30	(b)
Cs(I)	Solution 3	Soil A	Batch	3730	1387	8.5 days	Trace	30	(b)
Cs(I)	Solution 4	Soil A	Batch	8832	3417	8.5 days	Trace	30	(b)
Cs(I)	Solution 5	Soil A	Batch	5995	3632	8.5 days	Trace	30	(b)
Cs(I)	Solution 6	Soil A	Batch	4233	1321	8.5 days	Trace	30	(b)
Cs(I)	Solution 1	Soil A	Batch	13525	4741	21.5 days	Trace	30	(b)
Cs(I)	Solution 2	Soil A	Batch	6432	1219	21.5 days	Trace	30	(b)
Cs(I)	Solution 3	Soil A	Batch	7298	1098	21.5 days	Trace	30	(b)
Cs(I)	Solution 4	Soil A	Batch	8217	2380	21.5 days	Trace	30	(b)
Cs(I)	Solution 5	Soil A	Batch	6033	1534	21.5 days	Trace	30	(b)
Cs(I)	Solution 6	Soil A	Batch	11522	2154	21.5 days	Trace	30	(b)
Cs(I)	Solution 1	Soil B	Batch	2042	401	8.5 days	Trace	30	(b)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/Solid (mL/g)	Reference
Cs(I)	Solution 2	Soil B	Batch	1388	226	8.5 days	Trace	30	(b)
Cs(I)	Solution 3	Soil B	Batch	2291	819	8.5 days	Trace	30	(b)
Cs(I)	Solution 4	Soil B	Batch	3405	1215	8.5 days	Trace	30	(b)
Cs(I)	Solution 5	Soil B	Batch	5708	2635	8.5 days	Trace	30	(b)
Cs(I)	Solution 6	Soil B	Batch	3215	470	8.5 days	Trace	30	(b)
Cs(I)	Solution 1	Soil B	Batch	1505	320	21.5 days	Trace	30	(b)
Cs(I)	Solution 2	Soil B	Batch	1094	295	21.5 days	Trace	30	(b)
Cs(I)	Solution 3	Soil B	Batch	3016	722	21.5 days	Trace	30	(b)
Cs(I)	Solution 4	Soil B	Batch	5805	2109	21.5 days	Trace	30	(b)
Cs(I)	Solution 5	Soil B	Batch	3045	377	21.5 days	Trace	30	(b)
Cs(I)	Solution 6	Soil B	Batch	3253	80	21.5 days	Trace	30	(b)
Cs(I)	Solution L	Soil B	Batch	268	4	7 days	Trace	30	(b)
Cs(I)	Solution H	Soil B	Batch	25	1	7 days	Trace	30	(b)
Cs(I)	Hanford GW2	B850007A	Batch	2045	275	14 days	Trace	30	(c)
Cs(I)	Hanford GW2	B850010A	Batch	2090	305	14 days	Trace	30	(c)
Cs(I)	Hanford GW2	B850012A	Batch	2024	305	14 days	Trace	30	(c)
Cs(I)	Hanford GW2	B850014A	Batch	1970	40	14 days	Trace	30	(c)
Cs(I)	Hanford GW2	B850015A	Batch	1502	80	14 days	Trace	30	(c)
Cs(I)	Hanford GW2	B850016A	Batch	1536	270	14 days	Trace	30	(c)
Cs(I)	Hanford GW2	B850017A	Batch	2267	388	14 days	Trace	30	(c)
Cs(I)	Hanford GW2	B850019A	Batch	2862	396	14 days	Trace	30	(c)
Cs(I)	Hanford GW2	B850020A	Batch	2252	292	14 days	Trace	30	(c)
Cs(I)	Hanford GW2	B850021A	Batch	2073	409	14 days	Trace	30	(c)
Cs(I)	Hanford GW2	B850022A	Batch	1374	332	14 days	Trace	30	(c)
Cs(I)	Hanford GW2	B850023A	Batch	2295	280	14 days	Trace	30	(c)
Cs(I)	Hanford GW2	B850024A	Batch	2213	455	14 days	Trace	30	(c)
Cs(I)	Hanford GW2	B850025A	Batch	1717	484	14 days	Trace	30	(c)
Cs(I)	Hanford GW2	B850027A	Batch	1563	259	14 days	Trace	30	(c)
Cs(I)	Hanford GW2	B850029A	Batch	2129	423	14 days	Trace	30	(c)
Cs(I)	Hanford GW2	B850031A	Batch	4068	259	14 days	Trace	30	(c)
Cs(I)	Hanford GW2	B850032A	Batch	1792	315	14 days	Trace	30	(c)
Cs(I)	Hanford GW2	B850034A	Batch	1897	178	14 days	Trace	30	(c)
Cs(I)	Hanford GW2	B850035A	Batch	1435	133	14 days	Trace	30	(c)
Cs(I)	REDOX Liquor	MSG-1	Batch	28		4 days	Trace	10	(d)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/Solid (mL/g)	Reference
Cs(I)	REDOX Liquor	MSG-1	Batch	20		4 days	Trace	10	(d)
Cs(I)	REDOX Liquor	MSG-1	Batch	20	4	11 days	Trace	10	(d)
Cs(I)	Groundwater	Burbank loamy fine sand	Batch	8996		16 hrs	Trace	100	(e)
Cs(I)	Groundwater	Burbank loamy fine sand	Batch	3538		16 hrs	Trace	50	(e)
Cs(I)	Groundwater	Burbank loamy fine sand	Batch	1050		16 hrs	Trace	10	(e)
Cs(I)	Groundwater	Burbank loamy fine sand	Batch	326		16 hrs	Trace	5	(e)
Cs(I)	3 M NaNO ₃	Burbank loamy fine sand	Batch	466		16 hrs	Trace	100	(e)
Cs(I)	3 M NaNO ₃	Burbank loamy fine sand	Batch	380		16 hrs	Trace	50	(e)
Cs(I)	3 M NaNO ₃	Burbank loamy fine sand	Batch	271		16 hrs	Trace	10	(e)
Cs(I)	3 M NaNO ₃	Burbank loamy fine sand	Batch	206		16 hrs	Trace	5	(e)
Cs(I)	0.5 M NaCl	Burbank loamy fine sand	Batch	1091		16 hrs	Trace	100	(e)
Cs(I)	0.5 M NaCl	Burbank loamy fine sand	Batch	1445		16 hrs	Trace	50	(e)
Cs(I)	0.5 M NaCl	Burbank loamy fine sand	Batch	1354		16 hrs	Trace	10	(e)
Cs(I)	0.5 M NaCl	Burbank loamy fine sand	Batch	1173		16 hrs	Trace	5	(e)
Cs(I)	0.5 M CaCl ₂	Burbank loamy fine sand	Batch	5211		16 hrs	Trace	100	(e)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Cs(I)	0.5 M CaCl ₂	Burbank loamy fine sand	Batch	5362		16 hrs	Trace	50	(e)
Cs(I)	0.5 M CaCl ₂	Burbank loamy fine sand	Batch	2420		16 hrs	Trace	10	(e)
Cs(I)	0.5 M CaCl ₂	Burbank loamy fine sand	Batch	1264		16 hrs	Trace	5	(e)
Cs(I)	0.2 M NaCl	Ritzville A12	Batch	4869		1-2 wks*	Trace*	20*	(f)
Cs(I)	0.2 M NaCl	Ritzville B1	Batch	4332		1-2 wks*	Trace*	20*	(f)
Cs(I)	0.2 M NaCl	Ritzville C	Batch	3111		1-2 wks*	Trace*	20*	(f)
Cs(I)	0.2 M NaCl	Ritzville Cca	Batch	3529		1-2 wks*	Trace*	20*	(f)
Cs(I)	0.2 M NaCl	Burbank A12	Batch	2775		1-2 wks*	Trace*	20*	(f)
Cs(I)	0.2 M NaCl	Burbank AC	Batch	2680		1-2 wks*	Trace*	20*	(f)
Cs(I)	0.2 M NaCl	Burbank AC2	Batch	2573		1-2 wks*	Trace*	20*	(f)
Cs(I)	0.2 M NaCl	Burbank IC	Batch	1588		1-2 wks*	Trace*	20*	(f)
Cs(I)	0.2 M NaCl	Ephrata A12	Batch	3941		1-2 wks*	Trace*	20*	(f)
Cs(I)	0.2 M NaCl	Ephrata B1	Batch	4696		1-2 wks*	Trace*	20*	(f)
Cs(I)	0.2 M NaCl	Ephrata IB2	Batch	3491		1-2 wks*	Trace*	20*	(f)
Cs(I)	0.2 M NaCl	Ephrata IIC	Batch	1919		1-2 wks*	Trace*	20*	(f)
Cs(I)	T-106 Soln. 1	Sed 1	Batch	13.5		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 2	Sed 1	Batch	6		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 3	Sed 1	Batch	1.8		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 4	Sed 1	Batch	0.8		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 5	Sed 1	Batch	12		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 1	Sed 2	Batch	9.4		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 2	Sed 2	Batch	3.5		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 3	Sed 2	Batch	1.4		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 4	Sed 2	Batch	0.6		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 5	Sed 2	Batch	7.1		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 1	Sed 3	Batch	9.1		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 2	Sed 3	Batch	3.4		1-2 wks*	Trace*	20*	(g)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Cs(I)	T-106 Soln. 3	Sed 3	Batch	1.3		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 4	Sed 3	Batch	0.6		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 5	Sed 3	Batch	7.2		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 1	Sed 4	Batch	8.1		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 2	Sed 4	Batch	3.1		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 3	Sed 4	Batch	1.4		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 4	Sed 4	Batch	0.7		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 5	Sed 4	Batch	7.7		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 1	Sed 5	Batch	10.9		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 2	Sed 5	Batch	3.7		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 3	Sed 5	Batch	1.8		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 4	Sed 5	Batch	2.9		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 5	Sed 5	Batch	11.3		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 1	Sed 6	Batch	7.9		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 2	Sed 6	Batch	2		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 3	Sed 6	Batch	0.9		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 4	Sed 6	Batch	1.2		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 5	Sed 6	Batch	7.9		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 1	Sed 7	Batch	8.7		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 2	Sed 7	Batch	2.8		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 3	Sed 7	Batch	1.1		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 4	Sed 7	Batch	1.5		1-2 wks*	Trace*	20*	(g)
Cs(I)	T-106 Soln. 5	Sed 7	Batch	9.5		1-2 wks*	Trace*	20*	(g)
(a) Serne et al. 1993. (b) Gee and Campbell 1980. (c) Kaplan et al. 1998a. (d) Serne et al. 1998. (e) Hajek and Ames 1966. (f) Routson 1973. (g) Serne et al. 1998. *Data is best estimate.									

Table 6. Contaminant Distribution Coefficient Data for Nickel

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Ni(II)	Hanford GW	Trench-8	Batch	4.40E+02	3.00E+01	5 days	Trace	30	(a)
Ni(II)	Hanford GW	Trench-8	Batch	2.35E+03	6.80E+02	44 days	Trace	30	(a)
Ni(II)	Hanford GW3	218-E-12B	Batch	180.0		7 days	5.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	155.0		7 days	5.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	155.0		7 days	5.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	126.0		7 days	5.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	171.0		7 days	5.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	154.0		7 days	5.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	251.0		7 days	5.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	165.0		7 days	5.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	189.0		7 days	5.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	194.0		7 days	5.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	187.0		7 days	5.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	192.0		7 days	5.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	117.0		7 days	1.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	126.0		7 days	1.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	116.0		7 days	1.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	128.0		7 days	1.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	169.0		7 days	2.0E-6 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	163.0		7 days	2.0E-6 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	130.0		7 days	4.0E-7 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	118.0		7 days	4.0E-7 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	61.4		10 days	5.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	48.0		10 days	5.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	83.5		10 days	1.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	94.3		10 days	1.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	212.0		10 days	2.0E-6 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	195.0		10 days	2.0E-6 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	337.0		10 days	4.0E-7 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	255.0		10 days	4.0E-7 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	54.3		10 days	5.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	63.1		10 days	5.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	52.5		10 days	5.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	74.0		10 days	1.0E-5 M	40	(b,c)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Ni(II)	Hanford GW3	218-E-12B	Batch	95.9		10 days	1.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	87.0		10 days	1.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	169.0		10 days	2.0E-6 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	143.0		10 days	2.0E-6 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	168.0		10 days	2.0E-6 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	311.0		10 days	4.0E-7 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	259.0		10 days	4.0E-7 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	247.0		10 days	4.0E-7 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	179.0		26 days	5.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	184.0		26 days	5.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	135.0		26 days	1.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	170.0		26 days	1.0E-5 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	368.0		26 days	2.0E-6 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	264.0		26 days	2.0E-6 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	421.0		26 days	4.0E-7 M	40	(b,c)
Ni(II)	Hanford GW3	218-E-12B	Batch	592.0		26 days	4.0E-7 M	40	(b,c)
(a) Serne et al. 1993. (b) Rhoades et al. 1992. (c) Rhoades et al. 1994.									

Table 7. Contaminant Distribution Coefficient Data for Lead

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Pb(II)	Hanford GW3	218-E-12B	Batch	8230.0		7 days	1.0E-6 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	13700.0		7 days	1.0E-6 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	4050.0		7 days	1.0E-7 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	4140.0		7 days	1.0E-7 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	8510.0		7 days	1.0E-6 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	5060.0		7 days	1.0E-6 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	6160.0		7 days	3.0E-7 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	8140.0		7 days	3.0E-7 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	4720.0		7 days	1.0E-7 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	5140.0		7 days	1.0E-7 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	1330.0		7 days	3.0E-8 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	1670.0		7 days	3.0E-8 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	5080.0		7 days	1.0E-6 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	4990.0		7 days	1.0E-6 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	5530.0		7 days	1.0E-6 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	6070.0		7 days	1.0E-6 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	9000.0		7 days	1.0E-6 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	8730.0		7 days	1.0E-6 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	8130.0		7 days	1.0E-6 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	4520.0		7 days	1.0E-6 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	29200.0		10 days	1.0E-6 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	24800.0		10 days	1.0E-6 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	16000.0		10 days	3.0E-7 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	32500.0		10 days	3.0E-7 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	78700.0		10 days	1.0E-7 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	51000.0		10 days	1.0E-7 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	30400.0		10 days	3.0E-8 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	41400.0		10 days	3.0E-8 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	19200.0		10 days	1.0E-6 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	18000.0		10 days	1.0E-6 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	12500.0		10 days	1.0E-6 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	22400.0		10 days	3.0E-7 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	30400.0		10 days	3.0E-7 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	20100.0		10 days	3.0E-7 M	40	(a,b)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Pb(II)	Hanford GW3	218-E-12B	Batch	41000.0		10 days	1.0E-7 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	36500.0		10 days	1.0E-7 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	28700.0		10 days	1.0E-7 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	47900.0		10 days	3.0E-8 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	70800.0		10 days	3.0E-8 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	28100.0		10 days	3.0E-8 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	469000.0		30 days	1.0E-6 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	272000.0		30 days	1.0E-6 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	76500.0		30 days	1.0E-6 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	73600.0		30 days	1.0E-6 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	174000.0		30 days	1.0E-6 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	69800.0		30 days	1.0E-6 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	70700.0		30 days	1.0E-6 M	40	(a,b)
Pb(II)	Hanford GW3	218-E-12B	Batch	170000.0		30 days	1.0E-6 M	40	(a,b)
(a) Rhoades et al. 1992.									
(b) Rhoades et al. 1994.									

Table 8. Contaminant Distribution Coefficient Data for Plutonium

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Pu	Soln 1	Sed L	Batch	30		7 days	Trace	5	(a)
Pu	Soln 2	Sed L	Batch	5.24		7 days	Trace	5	(a)
Pu	Soln 3	Sed L	Batch	2.83		7 days	Trace	5	(a)
Pu	Soln 4	Sed L	Batch	1.27		7 days	Trace	5	(a)
Pu	Soln 5	Sed L	Batch	2.13		7 days	Trace	5	(a)
Pu	Soln 6	Sed L	Batch	10.42		7 days	Trace	5	(a)
Pu	Soln 7	Sed L	Batch	10.15		7 days	Trace	5	(a)
Pu	Soln 8	Sed L	Batch	3.16		7 days	Trace	5	(a)
Pu	Soln 9	Sed L	Batch	6.52		7 days	Trace	5	(a)
Pu	Soln 10	Sed L	Batch	3.61		7 days	Trace	5	(a)
Pu	Soln 11	Sed L	Batch	42.52		7 days	Trace	5	(a)
Pu	Soln 12	Sed L	Batch	20.14		7 days	Trace	5	(a)
Pu	Soln 13	Sed L	Batch	23.54		7 days	Trace	5	(a)
Pu	Soln 14	Sed L	Batch	94.93		7 days	Trace	5	(a)
Pu	Soln 15	Sed L	Batch	1.79		7 days	Trace	5	(a)
Pu	Soln 16	Sed L	Batch	4.03		7 days	Trace	5	(a)
Pu	Soln 17	Sed L	Batch	4.03		7 days	Trace	5	(a)
Pu	Soln 18	Sed L	Batch	1.12		7 days	Trace	5	(a)
Pu	Soln 19	Sed L	Batch	4.21		7 days	Trace	5	(a)
Pu	Soln 20	Sed L	Batch	>208		7 days	Trace	5	(a)
Pu	Soln 1	Sed P	Batch	34.5		7 days	Trace	5	(a)
Pu	Soln 2	Sed P	Batch	4.82		7 days	Trace	5	(a)
Pu	Soln 3	Sed P	Batch	2.57		7 days	Trace	5	(a)
Pu	Soln 4	Sed P	Batch	1.5		7 days	Trace	5	(a)
Pu	Soln 5	Sed P	Batch	1.98		7 days	Trace	5	(a)
Pu	Soln 6	Sed P	Batch	7.8		7 days	Trace	5	(a)
Pu	Soln 7	Sed P	Batch	12.1		7 days	Trace	5	(a)
Pu	Soln 8	Sed P	Batch	5.68		7 days	Trace	5	(a)
Pu	Soln 9	Sed P	Batch	5.17		7 days	Trace	5	(a)
Pu	Soln 10	Sed P	Batch	4.99		7 days	Trace	5	(a)
Pu	Soln 11	Sed P	Batch	34		7 days	Trace	5	(a)
Pu	Soln 12	Sed P	Batch	26		7 days	Trace	5	(a)
Pu	Soln 13	Sed P	Batch	28.5		7 days	Trace	5	(a)
Pu	Soln 14	Sed P	Batch	124.6		7 days	Trace	5	(a)
Pu	Soln 15	Sed P	Batch	2.84		7 days	Trace	5	(a)
Pu	Soln 16	Sed P	Batch	4.86		7 days	Trace	5	(a)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Pu	Soln 17	Sed P	Batch	4.06		7 days	Trace	5	(a)
Pu	Soln 18	Sed P	Batch	1.43		7 days	Trace	5	(a)
Pu	Soln 19	Sed P	Batch	6.53		7 days	Trace	5	(a)
Pu	Soln 20	Sed P	Batch	>194		7 days	Trace	5	(a)
Pu	Soln 1	Sed S	Batch	39		7 days	Trace	5	(a)
Pu	Soln 2	Sed S	Batch	7.6		7 days	Trace	5	(a)
Pu	Soln 3	Sed S	Batch	4.46		7 days	Trace	5	(a)
Pu	Soln 4	Sed S	Batch	5.96		7 days	Trace	5	(a)
Pu	Soln 5	Sed S	Batch	7.43		7 days	Trace	5	(a)
Pu	Soln 6	Sed S	Batch	49.3		7 days	Trace	5	(a)
Pu	Soln 7	Sed S	Batch	7.15		7 days	Trace	5	(a)
Pu	Soln 8	Sed S	Batch	11.2		7 days	Trace	5	(a)
Pu	Soln 9	Sed S	Batch	5.26		7 days	Trace	5	(a)
Pu	Soln 10	Sed S	Batch	7.92		7 days	Trace	5	(a)
Pu	Soln 11	Sed S	Batch	44.8		7 days	Trace	5	(a)
Pu	Soln 12	Sed S	Batch	19.3		7 days	Trace	5	(a)
Pu	Soln 13	Sed S	Batch	28.7		7 days	Trace	5	(a)
Pu	Soln 14	Sed S	Batch	145		7 days	Trace	5	(a)
Pu	Soln 15	Sed S	Batch	5.16		7 days	Trace	5	(a)
Pu	Soln 16	Sed S	Batch	8.49		7 days	Trace	5	(a)
Pu	Soln 17	Sed S	Batch	6.62		7 days	Trace	5	(a)
Pu	Soln 18	Sed S	Batch	2.6		7 days	Trace	5	(a)
Pu	Soln 19	Sed S	Batch	9.64		7 days	Trace	5	(a)
Pu	Soln 20	Sed S	Batch	>207		7 days	Trace	5	(a)
Pu	AAW, pH 1.7*	299-W18-6, -7	Batch	<1					(b)
Pu	AAW, pH 2	299-W18-6, -7	Batch	<1					(b)
Pu	AAW, pH 3	299-W18-6, -7	Batch	<1					(b)
Pu	DI Water pH 8.0	219-S-2	Batch	5.20E+03		1 day	7.70E-07	100	(c,d)
Pu	DI Water pH 8.0	219-S-2	Batch	4.10E+03		1 day	7.70E-07	100	(c,d)
Pu	DI Water pH 8.0	219-S-2	Batch	1.20E+03		1 day	7.70E-07	20	(c,d)
Pu	DI Water pH 8.0	219-S-2	Batch	2.50E+03		1 day	7.70E-07	10	(c,d)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Pu	DI Water pH 8.0	219-S-2	Batch	1.80E+03		1 day	1.00E-08	20	(c,d)
Pu	DI Water pH 8.0	219-S-2	Batch	2.20E+03		1 day	1.20E-07	20	(c,d)
Pu	DI Water pH 8.0	219-S-2	Batch	4.00E+03		1 day	2.10E-06	20	(c,d)
Pu	DI Water pH 8.0	219-S-2	Batch	4.00E+03		1 day	3.60E-06	20	(c,d)
Pu	DI Water pH 8.0	219-S-2	Batch	1.50E+03		1 day	1.30E-05	20	(c,d)
Pu	DI Water pH 8.0	219-S-2	Batch	506		1 day	2.10E-05	20	(c,d)
Pu	DI Water pH 0.5	219-S-2	Batch	28.4		1 day	7.70E-07	20	(c,d)
Pu	DI Water pH 2.1	219-S-2	Batch	2.50E+03		1 day	7.70E-07	20	(c,d)
Pu	DI Water pH 3.6	219-S-2	Batch	2.00E+03		1 day	7.70E-07	20	(c,d)
Pu	DI Water pH 4.5	219-S-2	Batch	2.50E+03		1 day	7.70E-07	20	(c,d)
Pu	DI Water pH 5.3	219-S-2	Batch	2.50E+03		1 day	7.70E-07	20	(c,d)
Pu	DI Water pH 6.1	219-S-2	Batch	1.30E+03		1 day	7.70E-07	20	(c,d)
Pu	DI Water pH 6.5	219-S-2	Batch	2.20E+03		1 day	7.70E-07	20	(c,d)
Pu	DI Water pH 7.3	219-S-2	Batch	2.00E+03		1 day	7.70E-07	20	(c,d)
Pu	DI Water pH 8.3	219-S-2	Batch	1.80E+03		1 day	7.70E-07	20	(c,d)
Pu	DI Water pH 9.4	219-S-2	Batch	1.80E+02		1 day	7.70E-07	20	(c,d)
Pu	DI Water pH 11.1	219-S-2	Batch	1.62E+02		1 day	7.70E-07	20	(c,d)
Pu	DI Water pH 12.0	219-S-2	Batch	8.50E+01		1 day	7.70E-07	20	(c,d)
Pu	DI Water pH 12.9	219-S-2	Batch	2.00E+03		1 day	7.70E-07	20	(c,d)
Pu	DI Water pH 14.2	219-S-2	Batch	2.00E+03		1 day	7.70E-07	20	(c,d)
(a) Delegard and Barney 1983. (b) Hajek and Knoll 1966. (c) Rhodes 1952. (d) Rhodes 1957. *Data is best estimate.									

Table 9. Contaminant Distribution Coefficient Data for Strontium

Species	Aqueous Phase	Solid Phase	Method	K _d (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Sr(II)	Hanford GW	CGS-1	Batch	17.9	1.3	4 days	Trace	30	(a)
Sr(II)	Hanford GW	CGS-1	Batch	18.8	2.9	14 days	Trace	30	(a)
Sr(II)	Hanford GW	CGS-1	Batch	20.7	3.2	35 days	Trace	30	(a)
Sr(II)	Acid Proc Waste	CGS-1	Batch	7.4	1.2	4 days	Trace	30	(a)
Sr(II)	Acid Proc Waste	CGS-1	Batch	11.7	0.8	14 days	Trace	30	(a)
Sr(II)	Acid Proc Waste	CGS-1	Batch	13	0.7	35 days	Trace	30	(a)
Sr(II)	Hanford GW	TBS-1	Batch	35.4	14.7	4 days	Trace	30	(a)
Sr(II)	Hanford GW	TBS-1	Batch	18.2	2.1	14 days	Trace	30	(a)
Sr(II)	Hanford GW	TBS-1	Batch	16.1	6.8	35 days	Trace	30	(a)
Sr(II)	Acid Proc Waste	TBS-1	Batch	8.1	6	4 days	Trace	30	(a)
Sr(II)	Acid Proc Waste	TBS-1	Batch	9.2	2.2	14 days	Trace	30	(a)
Sr(II)	Acid Proc Waste	TBS-1	Batch	7.8	1	35 days	Trace	30	(a)
Sr(II)	Hanford GW	Trench-8	Batch	23.4	4.1	5 days	Trace	30	(a)
Sr(II)	Hanford GW	Trench-8	Batch	18.1	4	44 days	Trace	30	(a)
Sr(II)	Solution 1	Soil A	Batch	133	13	8.5 days	Trace	30	(b)
Sr(II)	Solution 2	Soil A	Batch	238	21	8.5 days	Trace	30	(b)
Sr(II)	Solution 3	Soil A	Batch	40	3	8.5 days	Trace	30	(b)
Sr(II)	Solution 4	Soil A	Batch	86	8	8.5 days	Trace	30	(b)
Sr(II)	Solution 5	Soil A	Batch	222	28	8.5 days	Trace	30	(b)
Sr(II)	Solution 6	Soil A	Batch	17	1	8.5 days	Trace	30	(b)
Sr(II)	Solution 1	Soil A	Batch	112	1	21.5 days	Trace	30	(b)
Sr(II)	Solution 2	Soil A	Batch	181	12	21.5 days	Trace	30	(b)
Sr(II)	Solution 3	Soil A	Batch	38	8	21.5 days	Trace	30	(b)
Sr(II)	Solution 4	Soil A	Batch	74	3	21.5 days	Trace	30	(b)
Sr(II)	Solution 5	Soil A	Batch	207	18	21.5 days	Trace	30	(b)
Sr(II)	Solution 6	Soil A	Batch	21	3	21.5 days	Trace	30	(b)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/Solid (mL/g)	Reference
Sr(II)	Solution 1	Soil B	Batch	129	15	8.5 days	Trace	30	(b)
Sr(II)	Solution 2	Soil B	Batch	170	27	8.5 days	Trace	30	(b)
Sr(II)	Solution 3	Soil B	Batch	31	3	8.5 days	Trace	30	(b)
Sr(II)	Solution 4	Soil B	Batch	47	4	8.5 days	Trace	30	(b)
Sr(II)	Solution 5	Soil B	Batch	36	2	8.5 days	Trace	30	(b)
Sr(II)	Solution 6	Soil B	Batch	9	3	8.5 days	Trace	30	(b)
Sr(II)	Solution 1	Soil B	Batch	114	9	21.5 days	Trace	30	(b)
Sr(II)	Solution 2	Soil B	Batch	132	11	21.5 days	Trace	30	(b)
Sr(II)	Solution 3	Soil B	Batch	38	1	21.5 days	Trace	30	(b)
Sr(II)	Solution 4	Soil B	Batch	39	2	21.5 days	Trace	30	(b)
Sr(II)	Solution 5	Soil B	Batch	37	1	21.5 days	Trace	30	(b)
Sr(II)	Solution 6	Soil B	Batch	12	2	21.5 days	Trace	30	(b)
Sr(II)	Solution L	Soil B	Batch	6	1	7 days	Trace	30	(b)
Sr(II)	Solution H	Soil B	Batch	1	0.2	7 days	Trace	30	(b)
Sr(II)	Solution H	Soil B	Column	0.8		4 days	Trace	30	(b)
Sr(II)	Hanford GW2	B850007A	Batch	14.09	0.83	14 days	Trace	30	(c)
Sr(II)	Hanford GW2	B850010A	Batch	14.25	0.49	14 days	Trace	30	(c)
Sr(II)	Hanford GW2	B850012A	Batch	13.81	0.78	14 days	Trace	30	(c)
Sr(II)	Hanford GW2	B850014A	Batch	13.94	0.5	14 days	Trace	30	(c)
Sr(II)	Hanford GW2	B850015A	Batch	13.64	0.85	14 days	Trace	30	(c)
Sr(II)	Hanford GW2	B850016A	Batch	12.81	0.33	14 days	Trace	30	(c)
Sr(II)	Hanford GW2	B850017A	Batch	15.46	0.33	14 days	Trace	30	(c)
Sr(II)	Hanford GW2	B850019A	Batch	14.25	0.45	14 days	Trace	30	(c)
Sr(II)	Hanford GW2	B850020A	Batch	15.32	0.37	14 days	Trace	30	(c)
Sr(II)	Hanford GW2	B850021A	Batch	14.91	0.63	14 days	Trace	30	(c)
Sr(II)	Hanford GW2	B850022A	Batch	12.18	0.29	14 days	Trace	30	(c)
Sr(II)	Hanford GW2	B850023A	Batch	13.04	0.95	14 days	Trace	30	(c)
Sr(II)	Hanford GW2	B850024A	Batch	16.92	0.92	14 days	Trace	30	(c)
Sr(II)	Hanford GW2	B850025A	Batch	12.35	0.85	14 days	Trace	30	(c)
Sr(II)	Hanford GW2	B850027A	Batch	16.17	1.42	14 days	Trace	30	(c)
Sr(II)	Hanford GW2	B850029A	Batch	14.22	0.34	14 days	Trace	30	(c)
Sr(II)	Hanford GW2	B850031A	Batch	16.9	0.11	14 days	Trace	30	(c)
Sr(II)	Hanford GW2	B850032A	Batch	16.89	1.72	14 days	Trace	30	(c)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Sr(II)	Hanford GW2	B850034A	Batch	16.92	1.53	14 days	Trace	30	(c)
Sr(II)	Hanford GW2	B850035A	Batch	16.79	2.68	14 days	Trace	30	(c)
Sr(II)	0.038 M CaCl ₂	Trench-8	Col 100%Sat	1.8			Trace		(d)
Sr(II)	0.038 M CaCl ₂	Trench-8	Col 100%Sat	1.4			Trace		(d)
Sr(II)	0.038 M CaCl ₂	Trench-8	Col 72%Sat	2			Trace		(d)
Sr(II)	0.038 M CaCl ₂	Trench-8	Col 47%Sat	1			Trace		(d)
Sr(II)	0.038 M CaCl ₂	Trench-8	Col 26%Sat UFA	0.7			Trace		(d)
Sr(II)	0.038 M CaCl ₂	Trench-8	Col 26%Sat UFA	0.8			Trace		(d)
Sr(II)	Soln 1	Sed L	Batch	-0.89		7 days	Trace	5	(e)
Sr(II)	Soln 2	Sed L	Batch	-0.15		7 days	Trace	5	(e)
Sr(II)	Soln 3	Sed L	Batch	0.46		7 days	Trace	5	(e)
Sr(II)	Soln 4	Sed L	Batch	0.59		7 days	Trace	5	(e)
Sr(II)	Soln 5	Sed L	Batch	51.4		7 days	Trace	5	(e)
Sr(II)	Soln 6	Sed L	Batch	21.1		7 days	Trace	5	(e)
Sr(II)	Soln 7	Sed L	Batch	19.7		7 days	Trace	5	(e)
Sr(II)	Soln 8	Sed L	Batch	0.51		7 days	Trace	5	(e)
Sr(II)	Soln 9	Sed L	Batch	0.23		7 days	Trace	5	(e)
Sr(II)	Soln 10	Sed L	Batch	0.67		7 days	Trace	5	(e)
Sr(II)	Soln 11	Sed L	Batch	-0.08		7 days	Trace	5	(e)
Sr(II)	Soln 12	Sed L	Batch	0.27		7 days	Trace	5	(e)
Sr(II)	Soln 13	Sed L	Batch	0.6		7 days	Trace	5	(e)
Sr(II)	Soln 14	Sed L	Batch	493		7 days	Trace	5	(e)
Sr(II)	Soln 15	Sed L	Batch	0.29		7 days	Trace	5	(e)
Sr(II)	Soln 16	Sed L	Batch	0.13		7 days	Trace	5	(e)
Sr(II)	Soln 17	Sed L	Batch	0.06		7 days	Trace	5	(e)
Sr(II)	Soln 18	Sed L	Batch	0.56		7 days	Trace	5	(e)
Sr(II)	Soln 19	Sed L	Batch	0.63		7 days	Trace	5	(e)
Sr(II)	Soln 20	Sed L	Batch	49		7 days	Trace	5	(e)
Sr(II)	Soln 1	Sed P	Batch	-0.43		7 days	Trace	5	(e)
Sr(II)	Soln 2	Sed P	Batch	-0.22		7 days	Trace	5	(e)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Sr(II)	Soln 3	Sed P	Batch	0.92		7 days	Trace	5	(e)
Sr(II)	Soln 4	Sed P	Batch	0.6		7 days	Trace	5	(e)
Sr(II)	Soln 5	Sed P	Batch	45.2		7 days	Trace	5	(e)
Sr(II)	Soln 6	Sed P	Batch	28.7		7 days	Trace	5	(e)
Sr(II)	Soln 7	Sed P	Batch	16.8		7 days	Trace	5	(e)
Sr(II)	Soln 8	Sed P	Batch	0.79		7 days	Trace	5	(e)
Sr(II)	Soln 9	Sed P	Batch	0.34		7 days	Trace	5	(e)
Sr(II)	Soln 10	Sed P	Batch	0.82		7 days	Trace	5	(e)
Sr(II)	Soln 11	Sed P	Batch	0.21		7 days	Trace	5	(e)
Sr(II)	Soln 12	Sed P	Batch	0.24		7 days	Trace	5	(e)
Sr(II)	Soln 13	Sed P	Batch	0.5		7 days	Trace	5	(e)
Sr(II)	Soln 14	Sed P	Batch	487		7 days	Trace	5	(e)
Sr(II)	Soln 15	Sed P	Batch	0.12		7 days	Trace	5	(e)
Sr(II)	Soln 16	Sed P	Batch	0.06		7 days	Trace	5	(e)
Sr(II)	Soln 17	Sed P	Batch	-0.32		7 days	Trace	5	(e)
Sr(II)	Soln 18	Sed P	Batch	0.33		7 days	Trace	5	(e)
Sr(II)	Soln 19	Sed P	Batch	0.25		7 days	Trace	5	(e)
Sr(II)	Soln 20	Sed P	Batch	50.5		7 days	Trace	5	(e)
Sr(II)	Soln 1	Sed S	Batch	0.5		7 days	Trace	5	(e)
Sr(II)	Soln 2	Sed S	Batch	0.14		7 days	Trace	5	(e)
Sr(II)	Soln 3	Sed S	Batch	2.29		7 days	Trace	5	(e)
Sr(II)	Soln 4	Sed S	Batch	1.48		7 days	Trace	5	(e)
Sr(II)	Soln 5	Sed S	Batch	313		7 days	Trace	5	(e)
Sr(II)	Soln 6	Sed S	Batch	71		7 days	Trace	5	(e)
Sr(II)	Soln 7	Sed S	Batch	60.6		7 days	Trace	5	(e)
Sr(II)	Soln 8	Sed S	Batch	1.47		7 days	Trace	5	(e)
Sr(II)	Soln 9	Sed S	Batch	0.27		7 days	Trace	5	(e)
Sr(II)	Soln 10	Sed S	Batch	1.61		7 days	Trace	5	(e)
Sr(II)	Soln 11	Sed S	Batch	0.87		7 days	Trace	5	(e)
Sr(II)	Soln 12	Sed S	Batch	0.77		7 days	Trace	5	(e)
Sr(II)	Soln 13	Sed S	Batch	0.95		7 days	Trace	5	(e)
Sr(II)	Soln 14	Sed S	Batch	402		7 days	Trace	5	(e)
Sr(II)	Soln 15	Sed S	Batch	1.24		7 days	Trace	5	(e)
Sr(II)	Soln 16	Sed S	Batch	0.33		7 days	Trace	5	(e)
Sr(II)	Soln 17	Sed S	Batch	0.06		7 days	Trace	5	(e)
Sr(II)	Soln 18	Sed S	Batch	0.26		7 days	Trace	5	(e)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Sr(II)	Soln 19	Sed S	Batch	1.05		7 days	Trace	5	(e)
Sr(II)	Soln 20	Sed S	Batch	128		7 days	Trace	5	(e)
Sr(II)	REDOX Liquor	MSG-1	Batch	4		4 days	Trace	10	(f)
Sr(II)	REDOX Liquor	MSG-1	Batch	28		4 days	Trace	10	(f)
Sr(II)	REDOX Liquor	MSG-1	Batch	0.2	0.2	11 days	Trace	10	(f)
Sr(II)	Groundwater	Burbank loamy fine sand	Batch	48		16 hrs	Trace	100	(g)
Sr(II)	Groundwater	Burbank loamy fine sand	Batch	52		16 hrs	Trace	50	(g)
Sr(II)	Groundwater	Burbank loamy fine sand	Batch	51		16 hrs	Trace	10	(g)
Sr(II)	Groundwater	Burbank loamy fine sand	Batch	43		16 hrs	Trace	5	(g)
Sr(II)	3 M NaNO ₃	Burbank loamy fine sand	Batch	2.1		16 hrs	Trace	100	(g)
Sr(II)	3 M NaNO ₃	Burbank loamy fine sand	Batch	0.78		16 hrs	Trace	50	(g)
Sr(II)	3 M NaNO ₃	Burbank loamy fine sand	Batch	0.5		16 hrs	Trace	10	(g)
Sr(II)	3 M NaNO ₃	Burbank loamy fine sand	Batch	0.38		16 hrs	Trace	5	(g)
Sr(II)	0.5 M NaCl	Burbank loamy fine sand	Batch	7.3		16 hrs	Trace	100	(g)
Sr(II)	0.5 M NaCl	Burbank loamy fine sand	Batch	3.98		16 hrs	Trace	50	(g)
Sr(II)	0.5 M NaCl	Burbank loamy fine sand	Batch	1.98		16 hrs	Trace	10	(g)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Sr(II)	0.5 M NaCl	Burbank loamy fine sand	Batch	1.49		16 hrs	Trace	5	(g)
Sr(II)	3 M NaOAc	Burbank loamy fine sand	Batch	2.23		16 hrs	Trace	100	(g)
Sr(II)	3 M NaOAc	Burbank loamy fine sand	Batch	1.69		16 hrs	Trace	50	(g)
Sr(II)	3 M NaOAc	Burbank loamy fine sand	Batch	1.02		16 hrs	Trace	10	(g)
Sr(II)	3 M NaOAc	Burbank loamy fine sand	Batch	0.53		16 hrs	Trace	5	(g)
Sr(II)	0.2 M NaCl	Ritzville A12	Batch	21		Unknown			(h)
Sr(II)	0.2 M NaCl	Ritzville B1	Batch	27		Unknown			(h)
Sr(II)	0.2 M NaCl	Ritzville C	Batch	27		Unknown			(h)
Sr(II)	0.2 M NaCl	Ritzville Cca	Batch	24		Unknown			(h)
Sr(II)	0.2 M NaCl	Burbank A12	Batch	12		Unknown			(h)
Sr(II)	0.2 M NaCl	Burbank AC	Batch	15		Unknown			(h)
Sr(II)	0.2 M NaCl	Burbank AC2	Batch	21		Unknown			(h)
Sr(II)	0.2 M NaCl	Burbank IC	Batch	17		Unknown			(h)
Sr(II)	0.2 M NaCl	Ephrata A12	Batch	12		Unknown			(h)
Sr(II)	0.2 M NaCl	Ephrata B1	Batch	12		Unknown			(h)
Sr(II)	0.2 M NaCl	Ephrata IB2	Batch	17		Unknown			(h)
Sr(II)	0.2 M NaCl	Ephrata IIC	Batch	23		Unknown			(h)
Sr(II)	T-106 Soln. 1	Sed 1	Batch	3.91		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 2	Sed 1	Batch	1.74		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 3	Sed 1	Batch	0.023		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 4	Sed 1	Batch	0		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 5	Sed 1	Batch	18.4		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 1	Sed 2	Batch	2.9		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 2	Sed 2	Batch	1.17		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 3	Sed 2	Batch	0.047		1-2 wks*	Trace*	20*	(f,i)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/Solid (mL/g)	Reference
Sr(II)	T-106 Soln. 4	Sed 2	Batch	0		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 5	Sed 2	Batch	8.4		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 1	Sed 3	Batch	2.93		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 2	Sed 3	Batch	1.22		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 3	Sed 3	Batch	0.072		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 4	Sed 3	Batch	0		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 5	Sed 3	Batch	12.9		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 1	Sed 4	Batch	12.4		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 2	Sed 4	Batch	5.44		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 3	Sed 4	Batch	0.074		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 4	Sed 4	Batch	0		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 5	Sed 4	Batch	174		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 1	Sed 5	Batch	1.87		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 2	Sed 5	Batch	0.81		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 3	Sed 5	Batch	0.13		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 4	Sed 5	Batch	0.17		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 5	Sed 5	Batch	12.7		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 1	Sed 6	Batch	2.5		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 2	Sed 6	Batch	0.95		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 3	Sed 6	Batch	0.1		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 4	Sed 6	Batch	0.14		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 5	Sed 6	Batch	39.2		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 1	Sed 7	Batch	1.86		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 2	Sed 7	Batch	0.87		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 3	Sed 7	Batch	0.08		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 4	Sed 7	Batch	0.23		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	T-106 Soln. 5	Sed 7	Batch	20.2		1-2 wks*	Trace*	20*	(f,i)
Sr(II)	N-75 GW	N-94A(10-12)	Batch	27		3 days	Trace	30	(j)
Sr(II)	N-75 GW	N-94A(10-12)	Batch	32	1	10 days	Trace	30	(j)
Sr(II)	N-75 GW	N-94A(10-12)	Batch	30.3	0.6	31 days	Trace	30	(j)
Sr(II)	N-75 GW	N-94A(15-17)	Batch	24		3 days	Trace	30	(j)
Sr(II)	N-75 GW	N-94A(15-17)	Batch	28	4	10 days	Trace	30	(j)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Sr(II)	N-75 GW	N-94A(15-17)	Batch	28	2	31 days	Trace	30	(j)
Sr(II)	N-75 GW	N-94A(45)	Batch	273		3 days	Trace	30	(j)
Sr(II)	N-75 GW	N-94A(45)	Batch	266	6	10 days	Trace	30	(j)
Sr(II)	N-75 GW	N-94A(45)	Batch	252	18	31 days	Trace	30	(j)
Sr(II)	N-75 GW	N-95A(10)	Batch	41		3 days	Trace	30	(j)
Sr(II)	N-75 GW	N-95A(10)	Batch	47	5	10 days	Trace	30	(j)
Sr(II)	N-75 GW	N-95A(10)	Batch	49	4	31 days	Trace	30	(j)
Sr(II)	N-75 GW	N-95A(20)	Batch	25		3 days	Trace	30	(j)
Sr(II)	N-75 GW	N-95A(20)	Batch	36	15	10 days	Trace	30	(j)
Sr(II)	N-75 GW	N-95A(20)	Batch	26	3	31 days	Trace	30	(j)
Sr(II)	N-75 GW	N-95A(39)	Batch	124		3 days	Trace	30	(j)
Sr(II)	N-75 GW	N-95A(39)	Batch	131	16	10 days	Trace	30	(j)
Sr(II)	N-75 GW	N-95A(39)	Batch	124	1	31 days	Trace	30	(j)
Sr(II)	N-75 GW	N-96A(10-12)	Batch	33		3 days	Trace	30	(j)
Sr(II)	N-75 GW	N-96A(10-12)	Batch	35	2	10 days	Trace	30	(j)
Sr(II)	N-75 GW	N-96A(10-12)	Batch	36	3	31 days	Trace	30	(j)
Sr(II)	N-75 GW	N-96A(20-22)	Batch	17		3 days	Trace	30	(j)
Sr(II)	N-75 GW	N-96A(20-22)	Batch	21	3	10 days	Trace	30	(j)
Sr(II)	N-75 GW	N-96A(20-22)	Batch	20	0	31 days	Trace	30	(j)
Sr(II)	N-75 GW	N-96A(45-46)	Batch	63		3 days	Trace	30	(j)
Sr(II)	N-75 GW	N-96A(45-46)	Batch	49	14	10 days	Trace	30	(j)
Sr(II)	N-75 GW	N-96A(45-46)	Batch	49	17	31 days	Trace	30	(j)
(a) Serne et al. 1993. (b) Gee and Campbell 1980. (c) Kaplan et al. 1998b. (d) Lindenmeier et al. 1995. (e) Delegard and Barney 1983. (f) Serne et al. 1998. (g) Hajek and Ames 1966. (h) Routson 1973. (i) Ames and Rai 1978. (j) Serne and LeGore 1996. *Data is best estimate.									

Table 10. Contaminant Distribution Coefficient Data for Chromium

Species	Aqueous Phase	Solid Phase	Method	K _d (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Cr(VI)	Hanford GW	CGS-1	Batch	0.5	0.6	4 days	1.92E-06	30	(a)
Cr(VI)	Acid Proc Waste	CGS-1	Batch	7.5	2.3	4 days	1.92E-06	30	(a)
Cr(VI)	Hanford GW	CGS-1	Batch	-0.5	0.6	14 days	1.92E-06	30	(a)
Cr(VI)	Acid Proc Waste	CGS-1	Batch	13.3	4.4	14 days	1.92E-06	30	(a)
Cr(VI)	Hanford GW	CGS-1	Batch	0.3	1.3	35 days	1.92E-06	30	(a)
Cr(VI)	Acid Proc Waste	CGS-1	Batch	16.3	10.3	35 days	1.92E-06	30	(a)
Cr(VI)	Hanford GW	TBS-1	Batch	1.02	0.79	4 days	1.92E-06	30	(a)
Cr(VI)	Acid Proc Waste	TBS-1	Batch	2.49	1.98	4 days	1.92E-06	30	(a)
Cr(VI)	Hanford GW	TBS-1	Batch	-0.34	0.52	14 days	1.92E-06	30	(a)
Cr(VI)	Acid Proc Waste	TBS-1	Batch	13.5	8.5	14 days	1.92E-06	30	(a)
Cr(VI)	Hanford GW	TBS-1	Batch	-0.88	0.19	35 days	1.92E-06	30	(a)
Cr(VI)	Acid Proc Waste	TBS-1	Batch	22.1	6	35 days	1.92E-06	30	(a)
Cr(VI)	Hanford GW	Trench-8	Batch	-1.3	1.3	5 days	1.92E-06	30	(a)
Cr(VI)	Hanford GW	Trench-8	Batch	-3.4	6.6	44 days	1.92E-06	30	(a)
Cr(VI)	199-D5-42	100-D	Batch	0.3	0.1	4 days	1.92E-06	4	(b)
Cr(VI)	199-D5-42	100-D	Batch	0.0	0.0	4 days	1.92E-05	4	(b)
Cr(VI)	199-D5-42	100-D	Batch	0.0	0.05	4 days	1.92E-04	4	(b)
Cr(VI)	199-D5-42	100-D	Batch	0.2	0.1	14 days	1.92E-06	4	(b)
Cr(VI)	199-D5-42	100-D	Batch	0.0	0.0	14 days	1.92E-05	4	(b)
Cr(VI)	199-D5-42	100-D	Batch	0.0	0.0	14 days	1.92E-04	4	(b)
(a) Serne et al. 1993.									
(b) Serne, R. J. and K. E. Parker. 1999. <i>Estimate of Distribution Coefficients and Leachability of Hexavalent Chromium in 100--D Area Hanford Formation Sediments</i> . Bechtel Hanford, Inc., Richland, Washington (unpublished report).									

Table 11. Contaminant Distribution Coefficient Data for Iodine

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time (or Res. Time)	In. Soln. Conc.	Solution/Solid (mL/g)	Reference
I(-I)	Hanford GW	CGS-1	Batch	0.2	0.3	4 days	Trace	30	(a)
I(-I)	Acid Proc Waste	CGS-1	Batch	0.5	1.2	4 days	Trace	30	(a)
I(-I)	Hanford GW	CGS-1	Batch	0.9	0.4	14 days	Trace	30	(a)
I(-I)	Acid Proc Waste	CGS-1	Batch	4.4	0.7	14 days	Trace	30	(a)
I(-I)	Hanford GW	CGS-1	Batch	1.2	0.4	35 days	Trace	30	(a)
I(-I)	Acid Proc Waste	CGS-1	Batch	15.9	1.6	35 days	Trace	30	(a)
I(-I)	Hanford GW	TBS-1	Batch	0.4	0.6	4 days	Trace	30	(a)
I(-I)	Acid Proc Waste	TBS-1	Batch	4.7	0.2	4 days	Trace	30	(a)
I(-I)	Hanford GW	TBS-1	Batch	1.2	0.9	14 days	Trace	30	(a)
I(-I)	Acid Proc Waste	TBS-1	Batch	5.5	0.2	14 days	Trace	30	(a)
I(-I)	Hanford GW	TBS-1	Batch	2.6	0.4	35 days	Trace	30	(a)
I(-I)	Acid Proc Waste	TBS-1	Batch	5.8	0.6	35 days	Trace	30	(a)
I(-I)	Hanford GW	Trench-8	Batch	0.9	0.2	5 days	Trace	30	(a)
I(-I)	Hanford GW	Trench-8	Batch	1.5	2.4	44 days	Trace	30	(a)
I(-I)	Solution 1	Soil B	Batch	7	2	7 days	Trace	30	(b)
I(-I)	Solution 2	Soil B	Batch	8	1	7 days	Trace	30	(b)
I(-I)	Solution 3	Soil B	Batch	11	3	7 days	Trace	30	(b)
I(-I)	Solution 4	Soil B	Batch	15	5	7 days	Trace	30	(b)
I(-I)	Solution 5	Soil B	Batch	10	4	7 days	Trace	30	(b)
I(-I)	Solution 6	Soil B	Batch	4	2	7 days	Trace	30	(b)
I(-I)	Solution L	Soil B	Batch	18	22	7 days	Trace	30	(b)
I(-I)	Solution H	Soil B	Batch	4	6	7 days	Trace	30	(b)
I(-I)	Solution H	Soil B	Batch	0.04		4 days	Trace	30	(b)
I(-I)	Solution L	Soil A	Batch	0.06		4 days	Trace	30	(b)
I(-I)	Hanford GW2	B850007A	Batch	0	0.01	14 days	Trace	2	(c)
I(-I)	Hanford GW2	B850010A	Batch	-0.01	0.02	14 days	Trace	2	(c)
I(-I)	Hanford GW2	B850012A	Batch	0	0.03	14 days	Trace	2	(c)
I(-I)	Hanford GW2	B850014A	Batch	-0.03	0.02	14 days	Trace	2	(c)
I(-I)	Hanford GW2	B850015A	Batch	-0.03	0.03	14 days	Trace	2	(c)
I(-I)	Hanford GW2	B850016A	Batch	0.06	0.17	14 days	Trace	2	(c)
I(-I)	Hanford GW2	B850017A	Batch	0	0.02	14 days	Trace	2	(c)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time (or Res. Time)	In. Soln. Conc.	Solution/Solid (mL/g)	Reference
I(1)	Hanford GW2	B850019A	Batch	-0.01	0.01	14 days	Trace	2	(c)
I(1)	Hanford GW2	B850020A	Batch	-0.01	0.02	14 days	Trace	2	(c)
I(1)	Hanford GW2	B850021A	Batch	-0.01	0.01	14 days	Trace	2	(c)
I(1)	Hanford GW2	B850022A	Batch	0.12	0.04	14 days	Trace	2	(c)
I(1)	Hanford GW2	B850023A	Batch	0.13	0.06	14 days	Trace	2	(c)
I(1)	Hanford GW2	B850024A	Batch	0.02	0.03	14 days	Trace	2	(c)
I(1)	Hanford GW2	B850025A	Batch	0.09	0.05	14 days	Trace	2	(c)
I(1)	Hanford GW2	B850027A	Batch	0.06	0.05	14 days	Trace	2	(c)
I(1)	Hanford GW2	B850029A	Batch	0.23	0.06	14 days	Trace	2	(c)
I(1)	Hanford GW2	B850031A	Batch	0.04	0.07	14 days	Trace	2	(c)
I(1)	Hanford GW2	B850032A	Batch	-0.01	0.01	14 days	Trace	2	(c)
I(1)	Hanford GW2	B850034A	Batch	0.08	0.08	14 days	Trace	2	(c)
I(1)	Hanford GW2	B850035A	Batch	0.01	0.02	14 days	Trace	2	(c)
I(1)	GW-pH 8.1	Trench AE-3	Batch	0.22	0.01	14 days	Trace	2	(d)
I(1)	GW-pH 9.9	Trench AE-3	Batch	0.01	0.01	14 days	Trace	2	(d)
I(1)	GW-pH 10.2	Trench AE-3	Batch	-0.02	0.02	14 days	Trace	2	(d)
I(1)	GW-pH 11.0	Trench AE-3	Batch	-0.04	0.02	14 days	Trace	2	(d)
I(1)	GW-pH 11.9	Trench AE-3	Batch	0.01	0.01	14 days	Trace	2	(d)
I(1)	HGW4	Trench 94	Batch	0.19	0.1	7	Trace	2	(d)
I(1)	HGW4	Trench 94	Batch	2.26	1.18	199	Trace	2	(d)
I(1)	HGW4	Trench 94	Batch	3.31	0.11	261	Trace	2	(d)
I(1)	HGW4	Trench 94	Batch	9.8	0.73	331	Trace	2	(d)
I(1)	HGW4	Trench AE-3	Batch	2.09	1.14	7	Trace	2	(d)
I(1)	HGW4	Trench AE-3	Batch	2.13		199	Trace	2	(d)
I(1)	HGW4	Trench AE-3	Batch	3.26	1.96	261	Trace	2	(d)
I(1)	HGW4	Trench AE-3	Batch	4.72	3.03	331	Trace	2	(d)
I(1)	HGW4	TSB-1	Batch	1.11	0.08	7	Trace	2	(d)
I(1)	HGW4	TSB-1	Batch	0.04	0.1	199	Trace	2	(d)
I(1)	HGW4	TSB-1	Batch	10.44	1.49	261	Trace	2	(d)
I(1)	HGW4	TSB-1	Batch	6.86	1.38	331	Trace	2	(d)
(a) Serne et al. 1993. (b) Gee and Campbell 1980. (c) Kaplan et al. 1998b. (d) Kaplan et al. 1996.									

Table 12. Contaminant Distribution Coefficient Data for Nitrate

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc. (mg/L)	Solution/Solid (mL/g)	Reference
NO ₃ ⁻	Hanford GW	CGS-1	Batch	-1.1	3.8	4 days	10	30	(a)
NO ₃ ⁻	Acid Proc Waste	CGS-1	Batch	-0.5	0.8	4 days	260	30	(a)
NO ₃ ⁻	Hanford GW	CGS-1	Batch	5.9	8.7	14 days	10	30	(a)
NO ₃ ⁻	Acid Proc Waste	CGS-1	Batch	-1.9	2.2	14 days	260	30	(a)
NO ₃ ⁻	Hanford GW	CGS-1	Batch	-1.3	1.1	35 days	10	30	(a)
NO ₃ ⁻	Acid Proc Waste	CGS-1	Batch	-1.9	0.6	35 days	260	30	(a)
NO ₃ ⁻	Hanford GW	TBS-1	Batch	-27.2	0.53	4 days	10	30	(a)
NO ₃ ⁻	Acid Proc Waste	TBS-1	Batch	3.4	0.7	4 days	260	30	(a)
NO ₃ ⁻	Hanford GW	TBS-1	Batch	-27	0.75	14 days	10	30	(a)
NO ₃ ⁻	Acid Proc Waste	TBS-1	Batch	0.6	2.4	14 days	260	30	(a)
NO ₃ ⁻	Hanford GW	TBS-1	Batch	-26.6	0.5	35 days	10	30	(a)
NO ₃ ⁻	Acid Proc Waste	TBS-1	Batch	-4.8	1.8	35 days	260	30	(a)

Table 13. Contaminant Distribution Coefficient Data for Neptunium

Species	Aqueous Phase	Solid Phase	Method	K _d (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Np(V)	Hanford GW	Trench-8	Batch	1.35E+01	3.00E+00	5 days	Trace	30	(a)
Np(V)	Hanford GW	Trench-8	Batch	2.91E+01	3.60E+00	44 days	Trace	30	(a)
Np(V)	0.015 M NaNO ₃	Burbank Sand	Batch	3.9	0.12	1 day	Trace	2.5	(b,c)
Np(V)	0.030 M NaNO ₃	Burbank Sand	Batch	3.51	0.19	1 day	Trace	2.5	(b,c)
Np(V)	0.30 M NaNO ₃	Burbank Sand	Batch	3.28	0.13	1 day	Trace	2.5	(b,c)
Np(V)	0.75 M NaNO ₃	Burbank Sand	Batch	3.28	0.35	1 day	Trace	2.5	(b,c)
Np(V)	3.00 M NaNO ₃	Burbank Sand	Batch	3.19	0.22	1 day	Trace	2.5	(b,c)
Np(V)	0.002 M Ca(NO ₃) ₂	Burbank Sand	Batch	2.37	0.04	1 day	Trace	2.5	(b,c)
Np(V)	0.02 M Ca(NO ₃) ₂	Burbank Sand	Batch	0.93	0.07	1 day	Trace	2.5	(b,c)
Np(V)	0.05 M Ca(NO ₃) ₂	Burbank Sand	Batch	0.78	0.16	1 day	Trace	2.5	(b,c)
Np(V)	0.10 M Ca(NO ₃) ₂	Burbank Sand	Batch	0.62	0.04	1 day	Trace	2.5	(b,c)
Np(V)	0.20 M Ca(NO ₃) ₂	Burbank Sand	Batch	0.36	0.07	1 day	Trace	2.5	(b,c)
Np(V)	Distilled water	Burbank Sand	Batch	7.1	0.7	4 days	Trace	10	(d)
Np(V)	Distilled water	Burbank Sand	Batch	6.3	0.7	8 days	Trace	10	(d)
Np(V)	Distilled water	Burbank Sand	Batch	7.1	0.7	16 days	Trace	10	(d)
Np(V)	Distilled water	Burbank Sand	Batch	10.8	1.1	28 days	Trace	10	(d)
Np(V)	Distilled water	Burbank Sand	Batch	12.4	1.3	42 days	Trace	10	(d)
Np(V)	Distilled water	Burbank Sand	Batch	45	5	100 days	Trace	10	(d)
Np(V)	Soln 1	Sed L	Batch	9.4		7 days	Trace	5	(e)
Np(V)	Soln 2	Sed L	Batch	1.62		7 days	Trace	5	(e)
Np(V)	Soln 3	Sed L	Batch	1.75		7 days	Trace	5	(e)
Np(V)	Soln 4	Sed L	Batch	1.09		7 days	Trace	5	(e)
Np(V)	Soln 5	Sed L	Batch	2.95		7 days	Trace	5	(e)
Np(V)	Soln 6	Sed L	Batch	12.43		7 days	Trace	5	(e)
Np(V)	Soln 7	Sed L	Batch	2.43		7 days	Trace	5	(e)
Np(V)	Soln 8	Sed L	Batch	1.89		7 days	Trace	5	(e)
Np(V)	Soln 9	Sed L	Batch	1.76		7 days	Trace	5	(e)
Np(V)	Soln 10	Sed L	Batch	1.8		7 days	Trace	5	(e)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/Solid (mL/g)	Reference
Np(V)	Soln 11	Sed L	Batch	6.93		7 days	Trace	5	(e)
Np(V)	Soln 12	Sed L	Batch	4.14		7 days	Trace	5	(e)
Np(V)	Soln 13	Sed L	Batch	3.62		7 days	Trace	5	(e)
Np(V)	Soln 14	Sed L	Batch	92.07		7 days	Trace	5	(e)
Np(V)	Soln 15	Sed L	Batch	0.79		7 days	Trace	5	(e)
Np(V)	Soln 16	Sed L	Batch	1.61		7 days	Trace	5	(e)
Np(V)	Soln 17	Sed L	Batch	0.75		7 days	Trace	5	(e)
Np(V)	Soln 18	Sed L	Batch	1.22		7 days	Trace	5	(e)
Np(V)	Soln 19	Sed L	Batch	1.71		7 days	Trace	5	(e)
Np(V)	Soln 20	Sed L	Batch	296		7 days	Trace	5	(e)
Np(V)	Soln 1	Sed P	Batch	7.06		7 days	Trace	5	(e)
Np(V)	Soln 2	Sed P	Batch	0.95		7 days	Trace	5	(e)
Np(V)	Soln 3	Sed P	Batch	1.12		7 days	Trace	5	(e)
Np(V)	Soln 4	Sed P	Batch	1.13		7 days	Trace	5	(e)
Np(V)	Soln 5	Sed P	Batch	2.48		7 days	Trace	5	(e)
Np(V)	Soln 6	Sed P	Batch	10.5		7 days	Trace	5	(e)
Np(V)	Soln 7	Sed P	Batch	2.06		7 days	Trace	5	(e)
Np(V)	Soln 8	Sed P	Batch	2.12		7 days	Trace	5	(e)
Np(V)	Soln 9	Sed P	Batch	1.83		7 days	Trace	5	(e)
Np(V)	Soln 10	Sed P	Batch	2.03		7 days	Trace	5	(e)
Np(V)	Soln 11	Sed P	Batch	5.01		7 days	Trace	5	(e)
Np(V)	Soln 12	Sed P	Batch	4.34		7 days	Trace	5	(e)
Np(V)	Soln 13	Sed P	Batch	3.75		7 days	Trace	5	(e)
Np(V)	Soln 14	Sed P	Batch	75.2		7 days	Trace	5	(e)
Np(V)	Soln 15	Sed P	Batch	0.64		7 days	Trace	5	(e)
Np(V)	Soln 16	Sed P	Batch	1.11		7 days	Trace	5	(e)
Np(V)	Soln 17	Sed P	Batch	0.66		7 days	Trace	5	(e)
Np(V)	Soln 18	Sed P	Batch	1		7 days	Trace	5	(e)
Np(V)	Soln 19	Sed P	Batch	1.83		7 days	Trace	5	(e)
Np(V)	Soln 20	Sed P	Batch	142		7 days	Trace	5	(e)
Np(V)	Soln 1	Sed S	Batch	32.9		7 days	Trace	5	(e)
Np(V)	Soln 2	Sed S	Batch	3.6		7 days	Trace	5	(e)
Np(V)	Soln 3	Sed S	Batch	3.06		7 days	Trace	5	(e)
Np(V)	Soln 4	Sed S	Batch	2.4		7 days	Trace	5	(e)
Np(V)	Soln 5	Sed S	Batch	12.8		7 days	Trace	5	(e)
Np(V)	Soln 6	Sed S	Batch	118		7 days	Trace	5	(e)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Np(V)	Soln 7	Sed S	Batch	6.17		7 days	Trace	5	(e)
Np(V)	Soln 8	Sed S	Batch	4.66		7 days	Trace	5	(e)
Np(V)	Soln 9	Sed S	Batch	4.59		7 days	Trace	5	(e)
Np(V)	Soln 10	Sed S	Batch	5.42		7 days	Trace	5	(e)
Np(V)	Soln 11	Sed S	Batch	13.9		7 days	Trace	5	(e)
Np(V)	Soln 12	Sed S	Batch	13.1		7 days	Trace	5	(e)
Np(V)	Soln 13	Sed S	Batch	11.9		7 days	Trace	5	(e)
Np(V)	Soln 14	Sed S	Batch	222		7 days	Trace	5	(e)
Np(V)	Soln 15	Sed S	Batch	2.93		7 days	Trace	5	(e)
Np(V)	Soln 16	Sed S	Batch	2.88		7 days	Trace	5	(e)
Np(V)	Soln 17	Sed S	Batch	2.91		7 days	Trace	5	(e)
Np(V)	Soln 18	Sed S	Batch	2.05		7 days	Trace	5	(e)
Np(V)	Soln 19	Sed S	Batch	3.8		7 days	Trace	5	(e)
Np(V)	Soln 20	Sed S	Batch	>2090		7 days	Trace	5	(e)
Np(V)	HGW4	Trench 94	Batch	14.7	1.2	7	Trace	2	(f)
Np(V)	HGW4	Trench 94	Batch	19.9	0.5	77	Trace	2	(f)
Np(V)	HGW4	Trench AE-3	Batch	2.7	0.2	7	Trace	2	(f)
Np(V)	HGW4	Trench AE-3	Batch	13.5	0.5	77	Trace	2	(f)
Np(V)	HGW4	TSB-1	Batch	2.2	0.4	7	Trace	2	(f)
Np(V)	HGW4	TSB-1	Batch	3.6	3.7	77	Trace	2	(f)
(a) Serne et al. 1993. (b) Routson et al. 1975. (c) Routson et al. 1976. (d) Sheppard et al. 1976. (e) Delegard and Barney 1983. (f) Kaplan et al. 1996.									

Table 14. Contaminant Distribution Coefficient Data for Selenium

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Se(VI)	Hanford GW	CGS-1	Batch	0.9	1.1	4 days	1.27E-06	30	(a)
Se(VI)	Acid Proc Waste	CGS-1	Batch	-1.7	1.9	4 days	1.27E-06	30	(a)
Se(VI)	Hanford GW	CGS-1	Batch	3.1	0.8	14 days	1.27E-06	30	(a)
Se(VI)	Acid Proc Waste	CGS-1	Batch	-2.6	1.4	14 days	1.27E-06	30	(a)
Se(VI)	Hanford GW	CGS-1	Batch	-1.6	0.03	35 days	1.27E-06	30	(a)
Se(VI)	Acid Proc Waste	CGS-1	Batch	0.4	1.7	35 days	1.27E-06	30	(a)
Se(VI)	Hanford GW	TBS-1	Batch	-3.07	0.78	4 days	1.27E-06	30	(a)
Se(VI)	Acid Proc Waste	TBS-1	Batch	4.23	0.54	4 days	1.27E-06	30	(a)
Se(VI)	Hanford GW	TBS-1	Batch	-2.78	0.51	14 days	1.27E-06	30	(a)
Se(VI)	Acid Proc Waste	TBS-1	Batch	4.69	1.03	14 days	1.27E-06	30	(a)
Se(VI)	Hanford GW	TBS-1	Batch	-4.48	2.05	35 days	1.27E-06	30	(a)
Se(VI)	Acid Proc Waste	TBS-1	Batch	4.87	0.53	35 days	1.27E-06	30	(a)
Se(VI)	Hanford GW	Trench-8	Batch	-0.6	1.9	5 days	1.27E-06	30	(a)
Se(VI)	Hanford GW	Trench-8	Batch	-4.1	6.1	44 days	1.27E-06	30	(a)
Se(VI)	Solution 1	Soil B	Batch	27	2	7 days	Trace	30	(b)
Se(VI)	Solution 2	Soil B	Batch	26	2	7 days	Trace	30	(b)
Se(VI)	Solution 3	Soil B	Batch	16	3	7 days	Trace	30	(b)
Se(VI)	Solution 4	Soil B	Batch	38	12	7 days	Trace	30	(b)
Se(VI)	Solution 5	Soil B	Batch	40	2	7 days	Trace	30	(b)
Se(VI)	Solution 6	Soil B	Batch	72	10	7 days	Trace	30	(b)
Se(VI)	Hanford GW2	B850007A	Batch	7.77	0.08	14 days	Trace	2	(c)
Se(VI)	Hanford GW2	B850010A	Batch	6.8	0.54	14 days	Trace	2	(c)
Se(VI)	Hanford GW2	B850012A	Batch	6.22	0.38	14 days	Trace	2	(c)
Se(VI)	Hanford GW2	B850014A	Batch	6.79	0.32	14 days	Trace	2	(c)
Se(VI)	Hanford GW2	B850015A	Batch	6.24	0.28	14 days	Trace	2	(c)
Se(VI)	Hanford GW2	B850016A	Batch	6.85	0.58	14 days	Trace	2	(c)
Se(VI)	Hanford GW2	B850017A	Batch	8.64	0.38	14 days	Trace	2	(c)
Se(VI)	Hanford GW2	B850019A	Batch	8.93	0.05	14 days	Trace	2	(c)

Species	Aqueous Phase	Solid Phase	Method	K _d (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Se(VI)	Hanford GW2	B850020A	Batch	7.55	0.21	14 days	Trace	2	(c)
Se(VI)	Hanford GW2	B850021A	Batch	6.57	0.47	14 days	Trace	2	(c)
Se(VI)	Hanford GW2	B850022A	Batch	6.74	0.44	14 days	Trace	2	(c)
Se(VI)	Hanford GW2	B850023A	Batch	10.4	0.55	14 days	Trace	2	(c)
Se(VI)	Hanford GW2	B850024A	Batch	6.09	0.24	14 days	Trace	2	(c)
Se(VI)	Hanford GW2	B850025A	Batch	5.28	0.09	14 days	Trace	2	(c)
Se(VI)	Hanford GW2	B850027A	Batch	4.75	0.44	14 days	Trace	2	(c)
Se(VI)	Hanford GW2	B850029A	Batch	5.67	0.24	14 days	Trace	2	(c)
Se(VI)	Hanford GW2	B850031A	Batch	10.85	0.31	14 days	Trace	2	(c)
Se(VI)	Hanford GW2	B850032A	Batch	4.4	0.17	14 days	Trace	2	(c)
Se(VI)	Hanford GW2	B850034A	Batch	4.23	0.15	14 days	Trace	2	(c)
Se(VI)	Hanford GW2	B850035A	Batch	3.75	0.17	14 days	Trace	2	(c)
Se(VI)	GW-IS-0.05	Trench AE-3	Batch	3.31	0.57	14 days	Trace	2	(d)
Se(VI)	GW-IS-0.10	Trench AE-3	Batch	4.49	0.19	14 days	Trace	2	(d)
Se(VI)	GW-IS-0.50	Trench AE-3	Batch	4.47	0.06	14 days	Trace	2	(d)
Se(VI)	GW-IS-1.00	Trench AE-3	Batch	4.11	0.06	14 days	Trace	2	(d)
Se(VI)	GW-pH 8.1	Trench AE-3	Batch	5.78	0.28	14 days	Trace	2	(d)
Se(VI)	GW-pH 9.9	Trench AE-3	Batch	0.29	0.03	14 days	Trace	2	(d)
Se(VI)	GW-pH 10.2	Trench AE-3	Batch	0.19	0	14 days	Trace	2	(d)
Se(VI)	GW-pH 11.0	Trench AE-3	Batch	0.05	0.02	14 days	Trace	2	(d)
Se(VI)	GW-pH 11.9	Trench AE-3	Batch	0.04	0	14 days	Trace	2	(d)
(a) Serne et al. 1993. (b) Gee and Campbell 1980. (c) Kaplan et al. 1998a. (d) Kaplan et al. 1998b.									

Table 15. Contaminant Distribution Coefficient Data for Technetium

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Tc(VII)	Hanford GW1	CGS-1	Batch	-0.1	0.8	4 days	Trace	30	(a)
Tc(VII)	Hanford GW1	CGS-1	Batch	0.4	1.1	14 days	Trace	30	(a)
Tc(VII)	Hanford GW1	CGS-1	Batch	0.1	0.2	35 days	Trace	30	(a)
Tc(VII)	Acid Proc Waste	CGS-1	Batch	0.8	0.8	4 days	Trace	30	(a)
Tc(VII)	Acid Proc Waste	CGS-1	Batch	-0.4	0.3	14 days	Trace	30	(a)
Tc(VII)	Acid Proc Waste	CGS-1	Batch	-0.3	0.1	35 days	Trace	30	(a)
Tc(VII)	Hanford GW1	TBS-1	Batch	0.2	0.8	4 days	Trace	30	(a)
Tc(VII)	Hanford GW1	TBS-1	Batch	0.1	0.2	14 days	Trace	30	(a)
Tc(VII)	Hanford GW1	TBS-1	Batch	0.1	0.8	35 days	Trace	30	(a)
Tc(VII)	Acid Proc Waste	TBS-1	Batch	0.2	0.8	4 days	Trace	30	(a)
Tc(VII)	Acid Proc Waste	TBS-1	Batch	-0.2	0.5	14 days	Trace	30	(a)
Tc(VII)	Acid Proc Waste	TBS-1	Batch	0.3	1.2	35 days	Trace	30	(a)
Tc(VII)	Hanford GW1	Trench-8	Batch	-0.1	0.2	5 days	Trace	30	(a)
Tc(VII)	Hanford GW1	Trench-8	Batch	0.2	0.7	44 days	Trace	30	(a)
Tc(VII)	Solution 1	Soil A	Batch	-0.38	1.51	8.5 days	Trace	30	(b)
Tc(VII)	Solution 2	Soil A	Batch	-0.88	0.52	8.5 days	Trace	30	(b)
Tc(VII)	Solution 3	Soil A	Batch	-1.36	0.71	8.5 days	Trace	30	(b)
Tc(VII)	Solution 4	Soil A	Batch	0.41	0.34	8.5 days	Trace	30	(b)
Tc(VII)	Solution 5	Soil A	Batch	-2.34	0.98	8.5 days	Trace	30	(b)
Tc(VII)	Solution 6	Soil A	Batch	-0.81	0.39	8.5 days	Trace	30	(b)
Tc(VII)	Solution 1	Soil A	Batch	-2.77	0.23	21.5 days	Trace	30	(b)
Tc(VII)	Solution 2	Soil A	Batch	-1.13	2.38	21.5 days	Trace	30	(b)
Tc(VII)	Solution 3	Soil A	Batch	-0.04	0.21	21.5 days	Trace	30	(b)
Tc(VII)	Solution 4	Soil A	Batch	0.57	0.17	21.5 days	Trace	30	(b)
Tc(VII)	Solution 5	Soil A	Batch	0.54	0.65	21.5 days	Trace	30	(b)
Tc(VII)	Solution 6	Soil A	Batch	-0.51	1.2	21.5 days	Trace	30	(b)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Tc(VII)	Solution 1	Soil B	Batch	0.54	1.61	8.5 days	Trace	30	(b)
Tc(VII)	Solution 2	Soil B	Batch	-0.02	0.99	8.5 days	Trace	30	(b)
Tc(VII)	Solution 3	Soil B	Batch	0.85	0.32	8.5 days	Trace	30	(b)
Tc(VII)	Solution 4	Soil B	Batch	1.27	1.67	8.5 days	Trace	30	(b)
Tc(VII)	Solution 5	Soil B	Batch	-0.96	0.37	8.5 days	Trace	30	(b)
Tc(VII)	Solution 6	Soil B	Batch	-0.09	0.76	8.5 days	Trace	30	(b)
Tc(VII)	Solution 1	Soil B	Batch	0.07	0.32	21.5 days	Trace	30	(b)
Tc(VII)	Solution 2	Soil B	Batch	-1.62	0.6	21.5 days	Trace	30	(b)
Tc(VII)	Solution 3	Soil B	Batch	-0.31	0.3	21.5 days	Trace	30	(b)
Tc(VII)	Solution 4	Soil B	Batch	0.06	0.68	21.5 days	Trace	30	(b)
Tc(VII)	Solution 5	Soil B	Batch	0.52	0.51	21.5 days	Trace	30	(b)
Tc(VII)	Solution 6	Soil B	Batch	0.38	1.23	21.5 days	Trace	30	(b)
Tc(VII)	Solution L	Soil B	Batch	-3	2	7 days	Trace	30	(b)
Tc(VII)	Solution H	Soil B	Batch	-1	0.3	7 days	Trace	30	(b)
Tc(VII)	Solution L	Soil B	Column	0.03	0.01	4 days	Trace	30	(b)
Tc(VII)	Solution L	Soil A	Column	0.04		4 days	Trace	30	(b)
Tc(VII)	Hanford GW2	B850007A	Batch	-0.01	0.02	14 days	Trace	2	(c)
Tc(VII)	Hanford GW2	B850010A	Batch	-0.02	0.03	14 days	Trace	2	(c)
Tc(VII)	Hanford GW2	B850012A	Batch	0.01	0	14 days	Trace	2	(c)
Tc(VII)	Hanford GW2	B850014A	Batch	-0.01	0.03	14 days	Trace	2	(c)
Tc(VII)	Hanford GW2	B850015A	Batch	0	0.02	14 days	Trace	2	(c)
Tc(VII)	Hanford GW2	B850016A	Batch	-0.01	0.02	14 days	Trace	2	(c)
Tc(VII)	Hanford GW2	B850017A	Batch	-0.04	0.01	14 days	Trace	2	(c)
Tc(VII)	Hanford GW2	B850019A	Batch	0.02	0.02	14 days	Trace	2	(c)
Tc(VII)	Hanford GW2	B850020A	Batch	0	0.01	14 days	Trace	2	(c)
Tc(VII)	Hanford GW2	B850021A	Batch	0	0.02	14 days	Trace	2	(c)
Tc(VII)	Hanford GW2	B850022A	Batch	0	0.02	14 days	Trace	2	(c)
Tc(VII)	Hanford GW2	B850023A	Batch	-0.01	0.03	14 days	Trace	2	(c)
Tc(VII)	Hanford GW2	B850024A	Batch	0	0.02	14 days	Trace	2	(c)
Tc(VII)	Hanford GW2	B850025A	Batch	0.01	0.01	14 days	Trace	2	(c)
Tc(VII)	Hanford GW2	B850027A	Batch	0	0.01	14 days	Trace	2	(c)
Tc(VII)	Hanford GW2	B850029A	Batch	-0.01	0.03	14 days	Trace	2	(c)
Tc(VII)	Hanford GW2	B850031A	Batch	-0.03	0.04	14 days	Trace	2	(c)
Tc(VII)	Hanford GW2	B850032A	Batch	-0.01	0.01	14 days	Trace	2	(c)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
Tc(VII)	Hanford GW2	B850034A	Batch	-0.02	0.01	14 days	Trace	2	(c)
Tc(VII)	Hanford GW2	B850035A	Batch	-0.02	0.01	14 days	Trace	2	(c)
Tc(VII)	GW-IS-0.05	Trench AE-3	Batch	-0.16	0.04	14 days	Trace	2	(d)
Tc(VII)	GW-IS-0.10	Trench AE-3	Batch	-0.13	0	14 days	Trace	2	(d)
Tc(VII)	GW-IS-0.50	Trench AE-3	Batch	-0.28	0.01	14 days	Trace	2	(d)
Tc(VII)	GW-IS-1.00	Trench AE-3	Batch	3.94	0.99	14 days	Trace	2	(d)
Tc(VII)	GW-pH 8.1	Trench AE-3	Batch	-0.02	0.01	14 days	Trace	2	(d)
Tc(VII)	GW-pH 9.9	Trench AE-3	Batch	1.04	0.06	14 days	Trace	2	(d)
Tc(VII)	GW-pH 10.2	Trench AE-3	Batch	1.05	0.2	14 days	Trace	2	(d)
Tc(VII)	GW-pH 11.0	Trench AE-3	Batch	1.07	0.05	14 days	Trace	2	(d)
Tc(VII)	GW-pH 11.9	Trench AE-3	Batch	1.07	0.03	14 days	Trace	2	(d)
Tc(VII)	HGW4	Trench 94	Batch	-0.03	0.006	7	Trace	2	(e)
Tc(VII)	HGW4	Trench 94	Batch	-0.044	0.013	266	Trace	2	(e)
Tc(VII)	HGW4	Trench 94	Batch	0.057		328	Trace	2	(e)
Tc(VII)	HGW4	Trench 94	Batch	0.107	0.007	398	Trace	2	(e)
Tc(VII)	HGW4	Trench AE-3	Batch	-0.018	0.057	7	Trace	2	(e)
Tc(VII)	HGW4	Trench AE-3	Batch	-0.18	0.019	266	Trace	2	(e)
Tc(VII)	HGW4	Trench AE-3	Batch	0.023	0.011	328	Trace	2	(e)
Tc(VII)	HGW4	Trench AE-3	Batch	0.11	0.01	398	Trace	2	(e)
Tc(VII)	HGW4	TSB-1	Batch	-0.042	0.007	7	Trace	2	(e)
Tc(VII)	HGW4	TSB-1	Batch	-0.182	0.015	266	Trace	2	(e)
Tc(VII)	HGW4	TSB-1	Batch	0.049	0.029	328	Trace	2	(e)
Tc(VII)	HGW4	TSB-1	Batch	0.052	0.031	398	Trace	2	(e)
(a) Serne et al. 1993.									
(b) Gee and Campbell 1980.									
(c) Kaplan et al. 1998a.									
(d) Kaplan et al. 1998b.									
(e) Kaplan et al. 1996.									

Table 16. Contaminant Distribution Coefficient Data for Uranium

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
U(VI)	Hanford GW	CGS-1	Batch	1.6	3.4	4 days	2.10E-07	30	(a)
U(VI)	Hanford GW	CGS-1	Batch	-1.5	4.5	14 days	2.10E-07	30	(a)
U(VI)	Hanford GW	CGS-1	Batch	5.2	1.8	35 days	2.10E-07	30	(a)
U(VI)	Acid Proc Waste	CGS-1	Batch	147	39	4 days	2.10E-07	30	(a)
U(VI)	Acid Proc Waste	CGS-1	Batch	486	25	14 days	2.10E-07	30	(a)
U(VI)	Acid Proc Waste	CGS-1	Batch	1000	53	35 days	2.10E-07	30	(a)
U(VI)	Hanford GW	TBS-1	Batch	104	28	4 days	2.10E-07	30	(a)
U(VI)	Hanford GW	TBS-1	Batch	74	18	14 days	2.10E-07	30	(a)
U(VI)	Hanford GW	TBS-1	Batch	60.5	6.1	35 days	2.10E-07	30	(a)
U(VI)	Acid Proc Waste	TBS-1	Batch	109	66	4 days	2.10E-07	30	(a)
U(VI)	Acid Proc Waste	TBS-1	Batch	223	57	14 days	2.10E-07	30	(a)
U(VI)	Acid Proc Waste	TBS-1	Batch	579	330	35 days	2.10E-07	30	(a)
U(VI)	Hanford GW	Trench-8	Batch	1.9	1.4	5 days	2.10E-07	30	(a)
U(VI)	Hanford GW	Trench-8	Batch	2.4	0.6	44 days	2.10E-07	30	(a)
U(VI)	Hanford GW2	B850007A	Batch	0.94	0.12	14 days	8.40E-07	2	(b)
U(VI)	Hanford GW2	B850010A	Batch	0.67	0.08	14 days	8.40E-07	2	(b)
U(VI)	Hanford GW2	B850012A	Batch	0.64	0.1	14 days	8.40E-07	2	(b)
U(VI)	Hanford GW2	B850014A	Batch	0.67	0.05	14 days	8.40E-07	2	(b)
U(VI)	Hanford GW2	B850015A	Batch	0.74	0.05	14 days	8.40E-07	2	(b)
U(VI)	Hanford GW2	B850016A	Batch	0.57	0.04	14 days	8.40E-07	2	(b)
U(VI)	Hanford GW2	B850017A	Batch	0.68	0.15	14 days	8.40E-07	2	(b)
U(VI)	Hanford GW2	B850019A	Batch	0.51	0.08	14 days	8.40E-07	2	(b)
U(VI)	Hanford GW2	B850020A	Batch	0.65	0.08	14 days	8.40E-07	2	(b)
U(VI)	Hanford GW2	B850021A	Batch	0.57	0.09	14 days	8.40E-07	2	(b)
U(VI)	Hanford GW2	B850022A	Batch	0.59	0.08	14 days	8.40E-07	2	(b)
U(VI)	Hanford GW2	B850023A	Batch	0.58	0.05	14 days	8.40E-07	2	(b)
U(VI)	Hanford GW2	B850024A	Batch	0.55	0.05	14 days	8.40E-07	2	(b)
U(VI)	Hanford GW2	B850025A	Batch	0.56	0.07	14 days	8.40E-07	2	(b)
U(VI)	Hanford GW2	B850027A	Batch	0.59	0.08	14 days	8.40E-07	2	(b)
U(VI)	Hanford GW2	B850029A	Batch	0.5	0.13	14 days	8.40E-07	2	(b)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
U(VI)	Hanford GW2	B850031A	Batch	0.3	0.12	14 days	8.40E-07	2	(b)
U(VI)	Hanford GW2	B850032A	Batch	0.7	0.11	14 days	8.40E-07	2	(b)
U(VI)	Hanford GW2	B850034A	Batch	0.61	0.16	14 days	8.40E-07	2	(b)
U(VI)	Hanford GW2	B850035A	Batch	0.68	0.13	14 days	8.40E-07	2	(b)
U(VI)	Hanford GW	Trench-8	Col 100%Sat	2		12.4 hr	1.40E-07		(c)
U(VI)	Hanford GW	Trench-8	Col 100%Sat	0.5		0.6 hr	1.40E-07		(c)
U(VI)	Hanford GW	Trench-8	Col 100%Sat	2.7		5.9 hr	1.40E-07		(c)
U(VI)	Hanford GW	Trench-8	Col 65%Sat	1		32.4 hr	1.40E-07		(c)
U(VI)	Hanford GW	Trench-8	Col 70%Sat UFA	0.5		0.5 hr	2.60E-06		(c)
U(VI)	Hanford GW	Trench-8	Col 24%Sat UFA	0.2		0.6 hr	2.60E-06		(c)
U(VI)	Hanford GW	Trench-8	Col 63%Sat	1.1		77 hr	1.40E-07		(c)
U(VI)	Hanford GW	Trench-8	Col 43%Sat	1.1		31.5 hr	1.40E-07		(c)
U(VI)	Hanford GW	Trench-8	Col 29%Sat UFA	0.6		20.6 hr	2.60E-06		(c)
U(VI)	Hanford GW	Trench-8	Col 29%Sat UFA	0.6		20.6 hr	2.60E-06		(c)
U(VI)	Hanford GW2	MCS	Col 30%Sat UFA	0.48		0.13 hr	1.70E-06		(d)
U(VI)	Hanford GW2	MCS	Col 12%Sat UFA	0.16		0.088 hr	1.70E-06		(d)
U(VI)	Hanford GW2	TBS	Col 66%Sat UFA	1.42		0.32 hr	1.70E-06		(d)
U(VI)	Hanford GW2	TBS	Col 22%Sat UFA	0.39		0.17 hr	1.70E-06		(d)
U(VI)	Hanford GW2	WSL	Col 83%Sat UFA	4.05		0.38 hr	1.70E-06		(d)
U(VI)	Hanford GW2	WSL	Col 41%Sat UFA	1.81		0.34 hr	1.70E-06		(d)
U(VI)	Hanford GW2	TBS	Col 100%Sat UFA	0.79		0.24 hr	1.70E-06		(d)
U(VI)	Hanford GW2	WSL	Col 100%Sat UFA	1.83		0.23 hr	1.70E-06		(d)
U(VI)	0.0 mM NaClO ₄	Trench AE-3	Batch	1.99	0.1	14 days	7.10E-07	2	(e)
U(VI)	0.3 mM NaClO ₄	Trench AE-3	Batch	1.92	0.13	14 days	7.10E-07	2	(e)

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/ Solid (mL/g)	Reference
U(VI)	1.0 mM NaClO ₄	Trench AE-3	Batch	1.91	0.17	14 days	7.10E-07	2	(e)
U(VI)	1.7 mM NaClO ₄	Trench AE-3	Batch	2.1	0.22	14 days	7.10E-07	2	(e)
U(VI)	4.1 mM NaClO ₄	Trench AE-3	Batch	2.25	0.15	14 days	7.10E-07	2	(e)
U(VI)	14.0 mM NaClO ₄	Trench AE-3	Batch	2.44	0.44	14 days	7.10E-07	2	(e)
U(VI)	HGW pH 8.0	Trench AE-3	Batch	1.26	0.12	14 days	7.10E-07	2	(e)
U(VI)	HGW pH 8.0	Trench AE-3	Batch	1.27	0.55	14 days	7.10E-07	2	(e)
U(VI)	HGW pH 8.0	Trench AE-3	Batch	2.86	0.53	14 days	7.10E-07	2	(e)
U(VI)	HGW pH 8.0	Trench AE-3	Batch	3.09	0.25	14 days	7.10E-07	2	(e)
U(VI)	HGW pH 8.2	Trench AE-3	Batch	3.51	0.26	14 days	7.10E-07	2	(e)
U(VI)	HGW pH 11.0	Trench AE-3	Batch	546 (prec)	70	14 days	7.10E-07	2	(e)
U(VI)	HGW4	Trench 94	Batch	0.45	0.04	7	1.30E-06	2	(e)
U(VI)	HGW4	Trench 94	Batch	0.79	0.01	266	1.30E-06	2	(e)
U(VI)	HGW4	Trench 94	Batch	0.84	0.14	328	1.30E-06	2	(e)
U(VI)	HGW4	Trench 94	Batch	1.12	0.02	398	1.30E-06	2	(e)
U(VI)	HGW4	Trench 8B	Batch	1.62	0.12	7	1.30E-06	2	(e)
U(VI)	HGW4	Trench 8B	Batch	3.24	0.4	266	1.30E-06	2	(e)
U(VI)	HGW4	Trench 8B	Batch	3.41	0.25	328	1.30E-06	2	(e)
U(VI)	HGW4	Trench 8B	Batch	3.49	0.23	398	1.30E-06	2	(e)
U(VI)	HGW4	TSB	Batch	1.23	0.1	7	1.30E-06	2	(e)
U(VI)	HGW4	TSB	Batch	1.6	1.1	266	1.30E-06	2	(e)
U(VI)	HGW4	TSB	Batch	2.11	0.17	328	1.30E-06	2	(e)
U(VI)	HGW4	TSB	Batch	2.1	0.01	398	1.30E-06	2	(e)
(a) Serne et al. 1993. (b) Kaplan et al. 1998a. (c) Lindenmeier et al. 1995. (d) Gamerdinger et al. 1998. (e) Kaplan et al. 1996.									

Table 17. Contaminant Distribution Coefficient Data for Carbon Tetrachloride

Species	Aqueous Phase	Solid Phase	Method	Kd (mL/g)	Std. Dev.	Equil. Time	In. Soln. Conc.	Solution/Solid (mL/g)	Reference
CCl ₄	Hanford GW	299-W11-27 (200 ft)	Batch	-1.8		4 days	10000 ppb	40	(a)
CCl ₄	Hanford GW	299-W11-27 (200 ft)	Batch	0.0		4 days	10000 ppb	40	(a)
CCl ₄	Hanford GW	299-W11-27 (200 ft)	Batch	-0.2		4 days	5000 ppb	40	(a)
CCl ₄	Hanford GW	299-W11-27 (200 ft)	Batch	0.3		4 days	5000 ppb	40	(a)
CCl ₄	Hanford GW	299-W11-27 (200 ft)	Batch	-1.5		4 days	500 ppb	40	(a)
CCl ₄	Hanford GW	299-W11-27 (200 ft)	Batch	-1.5		4 days	500 ppb	40	(a)
CCl ₄	Hanford GW	299-W11-27 (200 ft)	Batch	-1.6		4 days	50 ppb	40	(a)
CCl ₄	Hanford GW	299-W11-27 (200 ft)	Batch	-0.6		4 days	50 ppb	40	(a)
CCl ₄	Hanford GW	299-W11-27 (200 ft)	Batch	-0.5		4 days	5 ppb	40	(a)
CCl ₄	Hanford GW	299-W11-27 (200 ft)	Batch	-0.6		4 days	5 ppb	40	(a)
(a) Unpublished results by K. J. Cantrell (1992). See Appendix C.									

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Appendix A

Aqueous Phase (Solution) Characteristics

Table A.1. Solution Characteristics

Solution	Sediment	Contact Time	pH	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	Si (ppm)	Sr (ppm)	Cl (ppm)	SO ₄ (ppm)	NO ₃ (ppm)	NO ₂ (ppm)	Al (ppm)	ClO ₄ (ppm)	Alk (as CO ₃ ²⁻) (ppm)	TOC (ppm)	Cations (meq/L)	Anions (meq/L)	Refer-ence	NaNO ₃ (M)	NaNO ₂ (M)	NaOH (M)	NaAlO ₂ (M)	Na ₂ CO ₃ (M)	Na ₂ SO ₄ (M)	Na ₃ PO ₄ (M)	NaF (M)	Na ₃ H EDTA (M)	Na ₄ EDTA (M)	HAA (M)	Citric A (M)	Ca(NO ₃) ₂ (M)	NH ₄ NO ₃ (M)	KNO ₃ (M)	(NH ₄) ₂ SO ₄ (M)			
Hanford GW1	none	0	8.14	60.4	14.4	34.9	10.2	16.7	0.25	30	70	7.8				67.5	1	5.99	4.68	(a)																			
Hanford GW1	CGS-1	35 days	7.9-8.4	58-60	15	42-43	9	17-18	0.22-0.27	27-31	59-64	15-17				138-150	NA	6.3	6.9-7.5	(a)																			
Hanford GW1	TBS-1	35 days	8.0-8.4	58-61	15	42-44	8-10	17-18	0.27-0.28	26-27	56-63	22-58				138	NA	6.2-6.4	7.0-7.5	(a)																			
Hanford GW1	Trench-8	44 days	8.2	53	15	33	7	15	0.22	29	80	29				NA	NA	5.5	NA	(a)																			
Acid Proc	none	0	3.5	65	9.8	192	4.1	0.17	<0.02	0.8	310	340				0	NA	13	12	(a)																			
Acid Proc	CGS-1	35 days	5.9-7.5	68-74	10	198-206	2.7-3.6	6.1-8.2	<0.02-0.04	3.4-4.0	246-289	362-428				0-38	NA	13	13	(a)																			
Acid Proc	TBS-1	35 days	4.1-4.3	68-77	12-13	193-198	3.9-4.4	13-14	<0.02-0.06	4.5-6.4	279-298	433-489				0	NA	13	13-14	(a)																			
Soln 1	Soil A	0	8.3 (22 day)	15	3.6	113	1.2			8	200	2				50				(b)																			
Soln 2	Soil A	0	8.1 (22 day)	9	1.8	17	0.6			2	39	0.5				16				(b)																			
Soln 3	Soil A	0	8.5 (22 day)	49	12.6	550	6.2			34	950	13				166				(b)																			
Soln 4	Soil A	0	7.8 (22 day)	30	5.1	138	1.3			271										(b)																			
Soln 5	Soil A	0	7.9 (22 day)	11	2.1	26	0.4			57										(b)																			
Soln 6	Soil A	0	7.8 (22 day)	126	18.3	760	6.7			1485										(b)																			
Soln 1	Soil B	0	8.1 (22 day)	4.2	3.4	5.8	3.7			0.5	7	6				24				(b)																			
Soln 2	Soil B	0	8.0 (22 day)	4.1	1.3	1	1.1			0.5	4.5	1				8				(b)																			
Soln 3	Soil B	0	8.3 (22 day)	6.4	11.3	23	17			0.8	37	32				64				(b)																			
Soln 4	Soil B	0	7.6 (22 day)	38	5.6	7.4	1.2			99										(b)																			
Soln 5	Soil B	0	7.6 (22 day)	8	1.3	1.8	0.6			21										(b)																			
Soln 6	Soil B	0	7.4 (22 day)	185	23	46	6.2			474										(b)																			
Soln H	Soil B	0	8.0 (7 day)	400		3450	5860					19830								(b)																			
Soln L	Soil B	0	8.3 (7 day)	80		3450	390					10170								(b)																			
Hanford GW2	299-E17-21	0	8.4	58	16	30	14	16.2		24	109	1.7				160	0.73			(c)																			
GW-IS-0.05	Trench AE-3	13	7.74	66	15	958	13	17			40																												
GW-IS-0.10	Trench AE-3	13	7.76	84	17	1793	17	15			41																												
GW-IS-0.50	Trench AE-3	13	7.73	95	18	5863	23	13			41																												
GW-IS-1.00	Trench AE-3	13	7.7	84	15	12173	31	9.8			41																												
GW-pH 8.1	Trench AE-3	13	8.1	43	10	79	14	19		39	39																												
GW-pH 9.9	Trench AE-3	13	9.9	1.6	0.13	170	8	22		75	39																												
GW-pH 10.2	Trench AE-3	13	10.2	1.5	0.11	166	6.6	32		42	39																												
GW-pH 11.0	Trench AE-3	13	11	1.6	0.08	227	6.8	60		74	39																												
GW-pH 11.9	Trench AE-3	13	11.9	1.7	0.1	418	5.8	122		33	40																												
0.015 M NaNO3	Burbank Sand	1 day	7.0 (soil)			345						930																											
0.030 M NaNO3	Burbank Sand	1 day	7.0 (soil)			690						1860																											
0.30 M NaNO ₃	Burbank Sand	1 day	7.0 (soil)			6900						18600																											
0.75 M NaNO ₃	Burbank Sand	1 day	7.0 (soil)			17250						46500																											
3.00 M NaNO ₃	Burbank Sand	1 day	7.0 (soil)			69000						186000																											

Solution	Sediment	Contact Time	pH	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	Si (ppm)	Sr (ppm)	Cl (ppm)	SO ₄ (ppm)	NO ₃ (ppm)	NO ₂ (ppm)	Al (ppm)	ClO ₄ (ppm)	Alk (as CO ₃ ²⁻) (ppm)	TOC (ppm)	Cations (meq/L)	Anions (meq/L)	Reference	NaNO ₃ (M)	NaNO ₂ (M)	NaOH (M)	NaAlO ₂ (M)	Na ₂ CO ₃ (M)	Na ₂ SO ₄ (M)	Na ₃ PO ₄ (M)	NaF (M)	Na ₃ H EDTA (M)	Na ₄ EDTA (M)	HAA (M)	Citric A (M)	Ca(NO ₃) ₂ (M)	NH ₄ NO ₃ (M)	KNO ₃ (M)	(NH ₄) ₂ SO ₄ (M)				
0.002 M Ca(NO ₃) ₂	Burbank Sand	1 day	7.0 (soil)	80								248																												
0.02 M Ca(NO ₃) ₂	Burbank Sand	1 day	7.0 (soil)	800								2480																												
0.05 M Ca(NO ₃) ₂	Burbank Sand	1 day	7.0 (soil)	2000								6200																												
0.10 M Ca(NO ₃) ₂	Burbank Sand	1 day	7.0 (soil)	4000								12400																												
0.20 M Ca(NO ₃) ₂	Burbank Sand	1 day	7.0 (soil)	8000								24800																												
Soln 1	L, P, and S	7 days																		(d)	2	2	1	0	0.05	0.01	0.01	0.01	0	0.05	0	0.03								
Soln 2	L, P, and S	7 days																		(d)	2	0	1	0.5	0.05	0.01	0.01	0	0.1	0	0.1	0	0							
Soln 3	L, P, and S	7 days																		(d)	0	0	4	0.5	0.05	0.01	0	0.01	0	0.05	0	0								
Soln 4	L, P, and S	7 days																		(d)	0	2	4	0.5	0.05	0	0.01	0	0.1	0	0	0								
Soln 5	L, P, and S	7 days																		(d)	2	2	4	0.5	0	0.01	0	0.01	0	0	0	0	0							
Soln 6	L, P, and S	7 days																		(d)	2	2	4	0	0.05	0	0.01	0	0	0	0	0	0.03							
Soln 7	L, P, and S	7 days																		(d)	2	2	1	0.5	0	0.01	0	0	0	0	0.1	0.03								
Soln 8	L, P, and S	7 days																		(d)	2	0	4	0	0.05	0	0	0	0	0	0.05	0.1	0							
Soln 9	L, P, and S	7 days																		(d)	0	2	1	0.5	0	0	0	0	0.1	0.05	0	0.03								
Soln 10	L, P, and S	7 days																		(d)	2	0	4	0	0	0	0	0.01	0.1	0	0.1	0.03								
Soln 11	L, P, and S	7 days																		(d)	0	2	1	0	0	0	0.01	0.01	0	0.05	0.1	0								
Soln 12	L, P, and S	7 days																		(d)	2	0	1	0	0	0.01	0.01	0	0.1	0.05	0	0								
Soln 13	L, P, and S	7 days																		(d)	0	0	1	0	0.05	0.01	0	0.01	0.1	0	0	0.03								
Soln 14	L, P, and S	7 days																		(d)	0	0	1	0.5	0.05	0	0.01	0.01	0	0	0.1	0.03								
Soln 15	L, P, and S	7 days																		(d)	0	0	4	0.5	0	0.01	0.01	0	0	0.05	0.1	0.03								
Soln 16	L, P, and S	7 days																		(d)	0	2	4	0	0.05	0.01	0	0	0.1	0.05	0.1	0.03								
Soln 17	L, P, and S	7 days																		(d)	2	2	1	0.5	0.05	0	0	0.01	0.1	0.05	0.1	0								
Soln 18	L, P, and S	7 days																		(d)	2	0	4	0.5	0	0	0.01	0.01	0.1	0.05	0	0.03								
Soln 19	L, P, and S	7 days																		(d)	0	2	4	0	0	0.01	0.01	0.01	0.1	0	0.1	0								
Soln 20	L, P, and S	7 days																		(d)	0	0	1	0	0	0	0	0	0	0	0	0	0							
REDOX Liquor	MSG-1	0	>14			4.75 M				0.27 M		5.99 M	0.67 M	0.41 M																										
		After	12.6			9.57 M				0.27 M		4.52 M	0.57 M	0.58 M																										
T-106 Soln. 1			12																	(e)	1	0			0									0.002	0.65	0.025	0			
T-106 Soln. 2			12																	(e)	4	0			0									0.002	0.65	0.025	0			
T-106 Soln. 3			12																	(e)	1	0			0									3.5	0.65	0.025	0			
T-106 Soln. 4			12																	(e)	4	0			0									3.5	0.65	0.025	0			
T-106 Soln. 5			12																	(e)	0.6	1.18			0.79									0.002	0.15	0.01	0.25			

Solution	Sediment	Contact Time	pH	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	Si (ppm)	Sr (ppm)	Cl (ppm)	SO ₄ (ppm)	NO ₃ (ppm)	NO ₂ (ppm)	Al (ppm)	ClO ₄ (ppm)	Alk (as CO ₃ ²⁻) (ppm)	TOC (ppm)	Cations (meq/L)	Anions (meq/L)	Refer-ence	NaNO ₃ (M)	NaNO ₂ (M)	NaOH (M)	NaAlO ₂ (M)	Na ₂ CO ₃ (M)	Na ₂ SO ₄ (M)	Na ₃ PO ₄ (M)	NaF (M)	Na ₃ H EDTA (M)	Na ₄ EDTA (M)	HAA (M)	Citric A (M)	Ca(NO ₃) ₂ (M)	NH ₄ NO ₃ (M)	KNO ₃ (M)	(NH ₄) ₂ SO ₄ (M)		
HGW3			8.14	48.8	14.6	32.1	9.9	16.4	0.25	27	75	<0.5	<0.3			67.5	1	5.29	4.6																			
HGW4			8.46	67.5	16.4	27.6	3	16.2	0.28	22	108	1.7				67.5	0.73																					
199-D5-42	100-D	4, 14 days	8.1	49.5	14.6	13.2	1.7	16.5		7.8	82.5	27.2				54.1				(f)																		
(a) Serne et al. 1993. (b) Gee and Campbell 1980. (c) Kaplan et al. 1998. (d) Delegard and Barney 1983. (e) Serne et al. 1998. (f) Serne and Parker 1999.																																						

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Appendix B

Solid Phase (Sediment) Characteristics

Table B.1. Sediment Characteristics

Sediment Sample No.	Fraction	Refer-ence	Well #, or Location	Depth (ft)	Gravel (wt. %)	Sand (wt. %)	Silt (wt. %)	Clay (wt. %)	Part. Den. (gm/cm³)	CEC (meq/100 gm)	CEC-Ca (wt. %)	CEC- Mg (wt. %)	CEC- Na (wt. %)	CEC-K (wt. %)	CaCO ₃ (wt. %)	SiO ₂ (wt. %)	Al ₂ O ₃ (wt. %)	Fe ₂ O ₃ (wt. %)	MnO ₂ (wt. %)	TOC (wt. %)	OC (wt. %)	Plag. (wt. %)	Qtz. (wt. %)	K- Feld. (wt. %)	Hornbl. (wt. %)	Mica (wt. %)	Kao./Serp. (wt. %)	Chlor. (wt. %)	Smect. (wt. %)	Verm. (wt. %)	Hyd. Ox. (wt. %)	Hydr Cond (cm/s)	Surface Area (m²/gm)				
CGS-1 Sand	Bulk	(a)	Quarry (W of 200-E)	near surf	82.5	15.6	1.2	0.7																													
	<2mm					89	7	4	2.73	2.6	89.2	9.6	0	1.2	0.96	0.36	0.24	0.41	0.04		0.067	35.4	35.2	9.3	1	8.6	1.6	2	3.9	1	1	1.01E-01					
	Sand																					41	38	10	1	7	1	2	-	<							
	Silt																					13	41	13	3	21	7	3	-	<							
	Clay																					<	5	<	<	19	4	2	57	14							
TBS-1	Bulk	(a)	Army Loop Road (S of 200-W)	near surf	< 1	79.2	14.8	5																													
	<2mm					80	15	5	2.72	6	90.6	9.1	0	0.3	1.87	0.38	0.25	0.28	0.03		0.021	20.5	51.3	3.6	1.8	11.7	0.2	2.6	5	0.3	0.9	6.56E-04					
	Sand																					22	56	4	2	13	<	3	-	<							
	Silt																					25	57	4	2	10	<	2	-	<							
	Clay																					<	1	<	<	5	4	1	84	5							
Trench-8	Bulk	(a)	W-5 Burial Ground Side Wall	20 ft	9.7	78.6	6.3	5.4																													
	<2mm					87	7	6	2.7	5.2	91.2	8.4	0	0.4	2	0.03	0.3	0.3	0.47		0.19	26.1	43	5.1	1.7	9.1	7.4	0.8	3.3	0.3	1.1	4.62E-02					
	Sand																					30	48	5	2	8	7	<	<	<							
	Silt																					12	35	13	<	18	17	6	<	<							
	Clay																					<	3	<	<	19	5	1	57	18							
Soil A	<2mm	(b)	Ringold, White Bluffs			45	44	11		12	55	32	12	1																			3.30E-05				
Soil B	<2mm	(b)	1618-10 BG	near surf		87	9.3	3.7		5	70	20	2	8																			1.83E-02				
B850007A		(c)	299-E17-21	45.9-47.9						5.07																											
B850010A		(c)	299-E17-21	57.8-59.8						4.73																											
B850012A		(c)	299-E17-21	69.4-71						4.6																											
B850014A		(c)	299-E17-21	80.3-82.8						4.62																											
B850015A		(c)	299-E17-21	90.5-93						4.11																											
B850016A		(c)	299-E17-21	100.5-103						2.32																											
B850017A		(c)	299-E17-21	109.8-112.2						4.98																											
B850019A		(c)	299-E17-21	121.0-123.5						4.72																											
B850020A		(c)	299-E17-21	129.7-132.2						4.67																											
B850021A		(c)	299-E17-21	141.5-144						4.56																											
B850022A		(c)	299-E17-21	151.9-154.4						7.33																											
B850023A		(c)	299-E17-21	160.4-162.9						8.41																											
B850024A		(c)	299-E17-21	180.7-182.7						9.03																											
B850025A		(c)	299-E17-21	189.7-191.9						6.63																											
B850027A		(c)	299-E17-21	194.3-201.3						8.36																											
B850029A		(c)	299-E17-21	210.9-211.4						7.77																											
B850031A		(c)	299-E17-21	214.6-222.6						10.98																											
B850032A		(c)	299-E17-21	229.0-231.2						8.39																											
B850034A		(c)	299-E17-21	236.1-238.1						6.21																											
B850035A		(c)	299-E17-21	239.5-241.5						6.65																											
Trench AE-3	Bulk	(d,e)	200 West Area Burial Ground	33	<1	41	50	9	2.74	6.4																						6.00E-06	14.8				
	<2mm					41	50	9																													
	Clay																									19			57	14							
Burbank Sand	<2mm	(f,g)	Eastern Washington				10.1	0.5		4.9					0.08																						
Burbank Sand		(h)	Richland, Washington			76	21.2	2.8		5.94											0.43																
MCS	<2mm	(i)	Hanford Site, Washington			98	<1	2																													

Sediment Sample No.	Fraction	Reference	Well #, or Location	Depth (ft)	Gravel (wt. %)	Sand (wt. %)	Silt (wt. %)	Clay (wt. %)	Part. Den. (gm/cm ³)	CEC (meq/100 gm)	CEC-Ca (wt. %)	CEC- Mg (wt. %)	CEC- Na (wt. %)	CEC-K (wt. %)	CaCO ₃ (wt. %)	SiO ₂ (wt. %)	Al ₂ O ₃ (wt. %)	Fe ₂ O ₃ (wt. %)	MnO ₂ (wt. %)	TOC (wt. %)	OC (wt. %)	Plag. (wt. %)	Qtz. (wt. %)	K- Feld. (wt. %)	Hornbl. (wt. %)	Mica (wt. %)	Kao./Serp. (wt. %)	Chlor. (wt. %)	Smect. (wt. %)	Verm. (wt. %)	Hyd. Ox. (wt. %)	Hydr Cond (cm/s)	Surface Area (m ² /gm)	
TBS	<2mm	(i)	Hanford Site, Washington			80	15	5																										
WSL	<2mm	(i)	Hanford Site, Washington			47	53 (Silt+Clay)	ND																										
L		(j,k)	E17-4	33-256	3.5	86.6	8.1	1.9		3.64					3.4																			
P		(j,k)	E33-22	85-194	6.8	85.5	6.4	1.25		3.5					1.9																			
S		(j,k)	W10-9	46-79	20.5	69.5	8.2	2.3		6.79					0																			
MSG-1	Bulk	(a,l)	Grout Vault (S of 200-E)		2.2	95.9	<1	2	2.82	7.8																								
	<2mm	(a,l)									84.5	12.7	0	2.8	0.83	0.36	0.24	0.41	0.04		0.023	41.5	46.1	<0.1	1.8	3.1	0.3	<0.1	5	0.2	1	7.32E-02		
	Sand	(a,l)																				45	50	<	2	3	<	<		<				
	Silt	(a,l)																				80	12	<	<	8	<	<		<				
	Clay	(a,l)																				<	<	<	<	5	6	1	85	3				
Ritzville A12	<2mm	(m)	Hanford Site, Washington	2-18"		47	46	7		12.8	63.4	27.7	1.2	7.7	0.8			1.44			0.34													
Ritzville B1	<2mm	(m)	Hanford Site, Washington	18-27"		54.7	42.5	2.5		11.9	39.5	57.7	0.8	1.9	1.3			0.89			0.27													
Ritzville C	<2mm	(m)	Hanford Site, Washington	27-41"		39.8	57.7	3.3		11.2	66.7	28	3.6	1.7	8.9			1.09			0.13													
Ritzville Cca	<2mm	(m)	Hanford Site, Washington	41-72"		55	42	3		7.9	62.6	19.9	15.3	2.3	4.2			1.11			0.17													
Burbank A12	<2mm	(m)	Hanford Site, Washington	3-16"		91.2	7.6	1.2		4.8	80.1	8	0.5	11.4	0.7			0.84			0.16													
Burbank AC	<2mm	(m)	Hanford Site, Washington	16-22"		88.7	10.6	0.7		4.9	94.9	<0.8	0.4	3.9	1.6			0.62			0.14													
Burbank AC2	<2mm	(m)	Hanford Site, Washington	22-30"		82.5	16.4	1.1		4.9	91.5	6.5	0.5	1.5	5.5			0.52			0.13													
Burbank IC	<2mm	(m)	Hanford Site, Washington	30"+		79.8	16.2	4		5.7	82.7	14.1	1.3	2	3.5			0.39			0.2													
Ephrata A12	<2mm	(m)	Hanford Site, Washington	3-12"		59	36.9	4.1		6	61.7	27.3	0.9	10.2	0.57			1.25			0.18													
Ephrata B1	<2mm	(m)	Hanford Site, Washington	12-15"		56.4	39.3	4.3		6.5	79.4	15.9	1.9	2.9	0.7			1.2			0.13													
Ephrata IB2	<2mm	(m)	Hanford Site, Washington	15-19"		62.9	31.4	5.7		7.6	74.9	20.9	3	1.2	0.87			0.98			0.29													
Ephrata IIC	<2mm	(m)	Hanford Site, Washington	19-24"		92.1	5.4	2.5		7.2	79.8	15.4	3.5	1.3	3.28			0.46			0.26													
Sed 1		(l)	W-10-113	20-40	39	?	?			6.73					1.24																			
Sed 2		(l)	W-10-113	45-65	20	?	?			6.16					1.3																			
Sed 3		(l)	W-10-113	70-80	5	88	7 (silt/clay)			5.95					2.6																			
Sed 4		(l)	W-10-24	102	41	?	?			7.88					37																			
Sed 5		(l)	W-10-109	15	59	41	0			6.73					0.95																			
Sed 6		(l)	W-10-23	100-105	10	70	20 (silt/clay)			5.28					7.65																			
Sed 7		(l)	W-10-112	85	0	62	38 (silt/clay)			6.96					13.2																			
218-E-12B		(n,o)	218-E-12B Burial Ground		32.7	67	0.26	0.04																										
218-E-12B	<2mm	(n,o)	218-E-12B Burial Ground			99.55	0.39	0.06		5.27	4.15	0.87	0.12		0.82	0.41	0.26	0.41	0.02	<0.01														
219-S-2		(p,q)	219-S crib	87	6	86	6	2		5					2																			
200-BP-1	<2mm	(r)	200-BP-1 operable unit crib	160 and 210																														
(a)	Serne et al. 1993.		(j)	Delegard and Barney 1983.																														
(b)	Gee and Campbell 1980.		(k)	Routson et al. 1981.																														
(c)	Kaplan et al. 1998.		(l)	Serne et al. 1998.																														
(d)	Kaplan et al. 1998.		(m)	Routson 1973.																														
(e)	Kaplan et al. 1996.		(n)	Rhoades et al. 1992.																														
(f)	Routson et al. 1975.		(o)	Rhoades et al. 1994.																														
(g)	Routson et al. 1976.		(p)	Rhodes 1957.																														
(h)	Sheppard et al. 1976.		(q)	Rhodes 1952.																														
(i)	Gamerdinger et al. 1998.		(r)	Cantrell and Serne 1993.																														

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Appendix C

Carbon Tetrachloride and Acetate K_d Values Appropriate for Hanford Soils

CARBON TETRACHLORIDE AND ACETATE K_d VALUES APPROPRIATE FOR HANFORD SOILS

Kirk Cantrell, 9/23/92

Summary

Based on previous laboratory adsorption data on soils with low organic content, it is expected that adsorption of carbon tetrachloride to Hanford soils (which are low in organic matter) will be very low. For example, Curtis et al. determined the K_d value for carbon tetrachloride between Bordon aquifer material (0.02% organic carbon) and a solution which simulates the native groundwater from this aquifer to be 0.16 ml/g.

Similarly low values were determined from analytical measurements of carbon tetrachloride measurements made on soils collected from Hanford well 2-W11-27 and solutions in contact with these soils. The K_d values calculated were 0.005, 0.165 and 0.012 ml/g for samples collected from depths of 248', 257' and 262', respectively.

Adsorption K_d values for carbon tetrachloride determined in our laboratories indicate that absorption of carbon tetrachloride onto Hanford soil from Hanford groundwater is essentially zero ($K_d = 0.0$ ml/g), within experimental error. This was true for carbon tetrachloride concentrations ranging from 5 to 10,000 ppb, both in the presence and absence of 10,000 ppb acetate. Adsorption of acetate was found to be significant at low acetate concentrations. The following K_d values were determined, 0.1 ml/g at 1000 ppm acetate in solution, 0.17 ml/g at 200 ppm acetate and 3.0 ml/g at 26 ppm acetate.

Based upon the data provided above, it is suggested that the likely range of K_d values appropriate to Hanford conditions for carbon tetrachloride is 0.0 ml/g to 0.2 ml/g.

Methods

The distribution coefficient or K_d is a measure of how well a chemical constituent adsorbs onto a solid material. The K_d is defined as the concentration of the constituent of interest in the solid phase divided by its concentration in the liquid phase. The distribution coefficient (K_d) of CCl_4 and acetate between 200 area soil and Hanford groundwater was determined according to the methods outlined in Relyea, Serne and Rai (1980).

Scintillation counting of ^{14}C labeled compounds was used to determine the concentrations in solution. Non-radioactive compounds were used as carriers to adjust the concentrations of the compound of interest in the initial solutions. The soil was collected from well 299-W11-27 on 11/5/91 at a depth of 200 feet. The Hanford groundwater was collected from well 6-S3-25.

The K_d values were measured by adding approximately one gram of soil to 40 ml of groundwater which was spiked with CCl_4 . These batch experiments were conducted in glass vials with teflon sealing caps. The concentration of CCl_4 on the solid phase was calculated as $[BV - E(V + X)]/W$, where B is the final concentration in the blank, V is the volume of groundwater added, E is the concentration in the sample effluent, X is the excess solution volume left from the pre-equilibration step, and W is the weight of solid aquifer material. Calculation of the K_d value was accomplished using equation 1

$$K_d = \frac{BV - E(V + X)}{WE} \quad (1)$$

Results

Results of our laboratory experiments are collected in Table 1. Most of the K_d values determined for CCl_4 are negative. Negative K_d values are not physically possible. Negative values resulted because the blanks actually lost slightly more CCl_4 than the vials which contained soil. From equation 1, we can see that this will result in a negative value for K_d . The vials used in these experiments were composed of glass with a teflon sealing cap. Apparently CCl_4 has an affinity for teflon because it should not absorb to any significant amount onto glass. The average value of K_d for CCl_4 determined from all the experiments was -0.8. Using the methods in Data Analysis for Scientists and Engineers (Meyer S. L., 1975), the average standard deviation of the K_d values was estimated to be 1.3. Based on these data it appears that the K_d value for CCl_4 on Hanford soil is 0.0 mL/g, with an upper bound value of approximately 1.3 mL/g.

Table 1. K_d values determined for carbon tetrachloride, both in the presence and absence of acetate, and K_d values for acetate.

CCl_4 Concentration (ppb)	Acetate Concentration (ppm)	$K_d(\text{CCl}_4)$ (mL/g)
10,000	0	-1.8
5,000	0	-0.2
500	0	-1.5
50	0	-1.6
5	0	-0.5
10,000	10	0.0
5,000	10	0.3
500	10	-1.5
50	10	-0.6
5	10	-0.6
		$K_d(\text{acetate})$ (mL/g)
0	1,000	0.1
0	200	0.2
0	26	3.1

C.1 References

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