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BINGHAM ENVIRONMENTAL

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PROJECT MEMORANDUM

TO: George Hellstrom - Envirocare of Utah, Inc.

FROM: David Waite - Bingham Environmental Inc.
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DATE: August 3, 1995

SUBJECT: Summary of Results
Radionuclide K_d Tests
Envirocare Disposal Landfills
Clive, Utah

This memorandum provides a summary of the distribution coefficient (K_d) testing performed for Envirocare by Barringer Laboratories Inc. (Barringer) located in Golden, Colorado. The objective of the K_d testing was to determine appropriate site-specific values for five radionuclides, utilizing test conditions which are representative of the soil, groundwater, and expected radionuclide concentration in the waste disposed in the LARW landfill cell. Site specific K_d values for Envirocare's site have not been determined in the past. The lowest value reported in the literature under varying conditions has been used in previous contaminant transport modeling.

APPROACH

The detailed approach is outlined in the *Work Plan* (Bingham, 1995), and ASTM method D 4319-83, *Standard Test Method for Distribution Ratios by the Short-Term Batch Method.* The Work Plan is presented in Appendix A, and the ASTM specification is presented in Appendix B. The Work Plan presents detailed procedures for determining site-specific distribution ratios for the five radionuclides, and methods of collecting soil and groundwater samples.

Several modifications to the Work Plan were made following the preparation of the Work Plan. The laboratory identified in the Work Plan is Controls for Environmental Pollution, Inc., the laboratory used for the tests was Barringer. Problems with the neptunium concentrate material Barringer received resulted in a contact solution that was at a lower activity than was proposed. Because of the low activity of the actual contact solution, the low-concentration test had levels of neptunium too low to measure accurately. The actual activity of the middle and high-concentration tests were approximately equal to the proposed low-concentration level. Therefore, it was possible to determine values from these two tests. The majority of the testing was performed in accordance with the Work Plan, with the exception of the aforementioned changes

The ASTM D 4319-83 test determines a distribution ratio (R_d) which is used to evaluate an appropriate distribution coefficient (K_d) for the particular radionuclide. The R_d value is a short-term laboratory value which is the ratio of the concentration sorbed to the soil to the concentration remaining in the liquid. The K_d is "identically defined as R_d for equilibrium conditions and for ion exchange-adsorption reactions only" (ASTM D 4319-83) and is a measure of long-term field conditions. Each value is a measure of the solid/liquid ratio; one for laboratory conditions and one for field conditions. In order to determine the K_d from the measured R_d, the differences between laboratory and field conditions must be accounted for. The ASTM method suggests that "To apply R_d values to field situations, an assumption such that $K_d = R_d$ is necessary." The method also suggests that such an assumption can only be made based on a detailed evaluation of the site and test conditions. Some conditions that may affect the determination of the K_d value from the R_d value include:

- differences in soil and contact solution chemistry
- time differences (short-term versus long-term)
- other fluids affecting field conditions (leachate)
- contact time and soil/liquid ratios (soil surface area)
- concentration of radionuclide
- temperature differences

Because the sand and groundwater used in the test were collected from the site and determined to be representative of site conditions, there would be minimal differences in soil/groundwater physical and analytical characteristics. The test is performed over three different time periods to evaluate if the R_d is time dependent. Differences in the measured values for the three tests are an indication of time-dependency. The leachate through the disposal cell is assumed to have minimal impacts on groundwater chemistry because of the large dilution effects of the groundwater and the buffering capacity of the groundwater. The ratio of soil/water (wt/wt) for the test is 1:4; actual field conditions would be closer to 1:1. The higher soil/water ratio for field conditions would result in more adsorption surface area for a given volume of water. The effects of concentration were accounted for by performing the test at three concentrations. Temperature differences between the laboratory test and field conditions are minimal. Because the R_d value is determined under conditions that directly reproduce, or are more conservative than field conditions; the K_d value proposed are assumed to equal the calculated laboratory R_d value.

LABORATORY TESTING

The tests were performed under conditions considered typical of the site. Silty sand (Unit 3) and groundwater from the site were used in the tests in order to simulate field conditions as closely as possible. Groundwater was collected from LARW compliance wells GW-20, GW-22, and GW-64. These wells are located around the perimeter of the LARW cell. Three samples of Unit 3 sand were collected from the south end of the LARW cell by Envirocare. The soil and groundwater was analyzed prior to performing the distribution ratio tests. The characteristics of the collected soil and groundwater were compared to existing data to verify the material used in the tests was representative of typical groundwater and the Unit 3 sand layer.

Analytical testing of the groundwater was performed by Barringer and is presented with the *Analytical Report Package* (Appendix D). The analytical results indicate that the groundwater samples collected were typical of groundwater at the site. Gradation analysis of the three individual and composite soil samples were performed by Bingham and are presented in Appendix C. The gradation of the soil used in the test was compared to gradation curves developed by Daniel B. Stephens Laboratory (1993) for the Unit 3 sand. The gradation for the sand used in the tests is similar to the typical gradations for the Unit 3 sand utilized in previous tests.

After it was determined the materials were typical of site groundwater and Unit 3 sand, the distribution ratio tests were initiated. The individual radionuclides were added to the groundwater sample to produce contact solutions of varying concentrations, although the ASTM test does not require different concentrations of contact solution. Three separate radionuclide contact solution concentrations were used because the waste received may vary from the maximum waste concentrations permitted. The results from the different concentrations were used to determine the sensitivity of R_d values with respect to radioisotope concentration. These contact solutions were then batched with the soil and the mixture was stirred. The R_d was determined from the ratio of the amount of radionuclide that adsorbed to the soil, and the amount that remained in solution.

LABORATORY RESULTS

Barringer Laboratory performed the R_d testing and they have summarized the results in the report provided in Appendix D. As seen in the report, some of the R_d values calculated for Tc-99 are negative. These negative values are due to the fact that some of the concentrations measured in the contact solution batched with the soil (batch solution) are greater than the initial concentrations of the solution prior to batching (head sample). Because the quantity of the material adsorbed to the soil is calculated from the concentration difference between the head sample and the batch solution; the soil concentration appears to be negative, resulting in a negative R_d. Because the soil is assumed to be clean (no radionuclides), it is improbable that the batch solution concentration would increase due to leaching of radionuclides from the soil.

There are at least two possible reasons for these negative R_d values. There are analytical variations, called 'uncertainty' values, that may result in a negative R_d; however, the uncertainty value is typically not large enough to result in a negative R_d value. Another possible reason for the negative value is some of the batch solution may hydrate (move into and remain in the soil pores) the soil producing a higher concentration in the batch solution; this is discussed in Barringer's report. Typically only a small portion of the total batch solution is analyzed; therefore, if some of the water hydrates the soil, the mass of the radionuclide remains the same and the volume of the liquid is reduced; resulting in a higher concentration.

To verify the values for Tc-99, the laboratory performed analysis of the initial and batched contact solutions utilizing a different analytical method than what was previously used. The solutions were originally analyzed by gas proportional counting and were subsequently tested using the liquid scintillation method. The second analytical tests resulted in all positive R_d values for the middle and higher concentration tests. Values for the lower concentration test still were negative. The results of the second tests were used in statistical evaluations. A summary of the R_d values developed from the laboratory procedures is provided in Table 1.

TABLE 1
SUMMARY OF AVERAGE LABORATORY R_d VALUES

CONCENTRATION	C-14	I-129	Np-237	Tc-99	U (nat)
Low	11.6	0.57	(3)	0.001 (1)	301.5
Medium	9.66	1.38	516.2	0.096	(4)
High	8.46	0.28	321.2	0.105	(4)
Average (2)	9.9	0.74	419	0.067	302

(1) Any negative value is set equal to 0.001
(2) Values from duplicate tests are not included in average
(3) Not performed
(4) No value was determined from these tests

STATISTICAL ANALYSIS

The R_d values were analyzed using the computer program SYSTAT (Systat, 1992) to determine if the data was normally distributed. The program plots the data against a normal probability plot, and if the data "follow a normal distribution the values will fall approximately along a straight line." (SYSTAT, 1992). If the R_d value reported by the laboratory is a negative value; the assumed value for use in the statistical evaluation is 0.001. Using an assumed value of 0.001 is considered to be appropriate because the value of 0.001 has previously been accepted by the Department of

Environmental Quality as a conservative value to use if the K_d value is not known.

Values from the duplicate tests were not included in the statistical evaluation. The duplicate values were not performed on all three concentrations or time intervals and therefore including the results would weight the final value to the duplicate sample. The duplicate is typically performed as an analytical check (laboratory QA/QC) to verify the result of the initial analysis. It does not provide results from an unique test and therefore was not used in the statistical evaluation.

The calculated R_d values based on the lab data, and several transformations of the calculated values, were analyzed to determine normalcy. Mathematical transformations of the R_d data were performed to determine a normally distributed data set to predict mean values. The transformations analyzed by the program include; square root, inverse of the square root, log base 10, natural log, and arcsin. The results of the statistical evaluation are provided in Appendix E. The transformation of the data set that was determined to be normally distributed, and the average of the transformed data set for each of the radionuclides, is provided in Table 2

TABLE 2
SUMMARY OF NORMALLY DISTRIBUTED TRANSFORMATION AND STATISTICAL ANALYSIS OF R_d VALUES

	C-14	I-129	Np-237	Tc-99	U (nat)
Transformation	(square root)$^{-1}$	none	none	none	none
Average K_d Value	9.6	0.74	420	0.07	6.0 (1)

(1) Value is the average of the 7 day and 16 day tests for the lowest concentration test.

The middle and highest concentration uranium tests resulted in the uranium precipitating from the batch solution. The lowest concentration test was the only test that yielded R_d values. The R_d from the 3 day uranium test was an order of magnitude higher than the 7 and 16 day tests; therefore, the statistical average was calculated from the results of the 7 and 16 day tests of the lower concentration.

CONCLUSIONS

K_d values for the five radionuclides have been developed based on the laboratory R_d data; the statistical evaluation of the results are presented in Table 3.

TABLE 3
PROPOSED K_d VALUES

RADIONUCLIDE	RANGE IN LITERATURE	PROPOSED K_d VALUE
C-14	0.01 (1,2)	9.0
I-129	0.2 - 1.5 (2)	0.7
Np-237	0.2 - 400 (2)	400
Tc-99	0.001 - 400 (2)	0.07
U (nat)	0.1 - 1,000,000 (1)	6.0

(1) Looney, B.B., M.W. Grant, and C.M. King, *Estimation of Geochemical Parameters for Assessing Subsurface Transport at the Savannah River Plant*, E.I. du Pont De Nemours & Co., Environmental Information Document, DPST-85-904, March 1987.

(2) Sheppard, M.I., D.I. Beals, D.H. Thibault, and P. O'Conner, *Soil Nuclide Distribution Coefficients and Their Distributions*, Atomic Energy of Canada Limited, AECL-8364, December 1984.

The proposed K_d for each of the radionuclides, with the exception of C-14, fall within the range of values presented in available literature. A brief analysis of the data and the rationale for the proposed values is presented below for each of the radionuclides.

Carbon-14

Based on a statistical evaluation of laboratory testing the proposed K_d value for carbon-14 is 9.0 mg/l. The calculated R_d values are relatively consistent over both time and varying concentrations with no negative values, indicating credible results. There is a general trend of decreasing R_d with time for carbon. The R_d value typically dropped significantly (7 to 38%) between the 3 and 7 day test. The drop between the 7 day and the 14 day test was smaller (1 to 7%). The value appears to approach a equilibrium with time. The site-specific value is significantly larger than the value presented in Looney (1987) for all soil types. Sheppard suggests that the K_d probably increases with increasing calcium concentration and suggests a retardation factor of greater than 10 for a bentonite/quartz mixture.

Iodine-129

Based on a statistical evaluation of laboratory testing the proposed K_d value for iodine-129 is 0.7 mg/l. With the exception of the high concentration-7 day duplicate, the R_d values were all positive. The site-specific value is about average for the values typical of a sandy soil (Sheppard, 1984).

Neptunium-237

Based on a statistical evaluation of laboratory testing the proposed K_d value for neptunium-237 is 400 mg/l. The concentration of the contact solution used in the test was lower than the proposed value presented in the Work Plan, although the values are all positive and are reasonably consistent. The proposed site-specific value is at the higher end of the range of the sand K_d values presented in Sheppard (1984). The range of values for sand is 0.2 to 400, and the range for clay is 41 to 3,200.

Technetium-99

Based on a statistical evaluation of laboratory testing the proposed K_d value for technetium-99 is 0.07 mg/l. This proposed value is based on the values calculated from the verification analysis (second set of analysis) performed by the laboratory. The second analytical method is considered more accurate than the analytical method previously performed (verbal communication with Barringer, 7/27/95). The data from the second set of analysis also appears to be more consistent than the first test. All R_d values from the middle and high concentration tests are positive and fall within a reasonable range (0.07 to 0.14). The values from these tests also show a consistent decrease in R_d with time. The R_d value typically dropped 20 to 30 % between the 3 and 7 day test, and the 7 day and the 14 day test; for a total decrease of about 50% between the 3 and 14 day tests. The negative values from the lower concentration tests are accounted for by setting them equal to 0.001 for statistical evaluation. The proposed site-specific value is near the lowest values reported in literature. The range of K_d values for a sandy soil ranged from 0.001 to 400 (Sheppard, 1984).

Uranium (natural)

Based on a statistical evaluation of laboratory testing the proposed K_d value for all uranium isotopes is 6.0 mg/l. Values for the middle and highest concentrations were not utilized because the uranium was observed to precipitate out of the contact solution at these higher concentrations. It was possible to determine a value for the lower concentration because the uranium remained in solution. The lower-concentration value is assumed to represent field conditions; due to precipitation occurring at the higher concentrations.

The R_d value for the 3 day test was an order of magnitude larger than the value of the 7 and 16 day tests. Therefore; in order to remain conservative, the proposed value is the average of the 7 and the 16 day tests. The values for these tests was 5.8 and 6.2, indicating little variance. The proposed site-specific value is in the middle range of values reported in literature for a sandy soil. The range of K_d values for a sandy soil ranged from 0.13 to 16, the range for a clay soil ranged from 200 to 8.0E+5 (Sheppard, 1984).

APPENDIX A

WORK PLAN

WORK PLAN

DISTRIBUTION RATIO (K_d) TESTING

ENVIROCARE OF UTAH
LOW ACTIVITY RADIOACTIVE WASTE (LARW) DISPOSAL SITE
SOUTH CLIVE, UTAH

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SECTION 1

PROJECT DESCRIPTION

1.1 GENERAL OVERVIEW

This work plan presents the procedure for determining site-specific distribution ratios (K_d's) for five radionuclides at Envirocare's Low Activity Radioactive Waste (LARW) disposal cell. The new K_d values derived from laboratory testing is anticipated to be used in continuing contaminant transport modelling for the Envirocare facility. Bingham Environmental Inc. (Bingham) has previously performed contaminant transport modelling for both metals and radionuclides at the Envirocare LARW site. The results are presented in the *Report of Contaminant Transport Modelling*, hereafter called the RCT (Bingham, 1993).

1.2 OBJECTIVES

The objective of the K_d testing presented in this work plan is to determine appropriate saturated-sand K_d values for five radionuclides, utilizing test conditions which are representative of the soil, groundwater, and expected radionuclide concentration conditions at the site. Previous K_d values used in contaminant transport modelling were the lowest values reported in literature and were not based on actual site conditions. Site soils and groundwater will be collected and used for the proposed K_d tests. Varying concentrations of the five radionuclides will be added to the groundwater, modelling the discharge of leachate from the waste cell into the groundwater. These site-specific K_d values will be used to reevaluate previous contaminant transport modelling performed in the saturated zone (shallow aquifer) as described in the RCT.

1.3 PROJECT SCHEDULE

The project is anticipated to require 7 weeks from the delivery of groundwater and soil samples to Bingham Material Laboratory (Bingham Laboratory). Laboratory analysis of the soil and groundwater samples is estimated to require approximately 6 weeks. The remaining week will be required for analysis of laboratory reports and preparation of a summary report.

1.4 PROJECT RESPONSIBILITIES

Envirocare will collect and deliver the specified Unit 3 soil and groundwater materials to Bingham Laboratory. Bingham Laboratory will then perform testing on the soil to demonstrate the materials representativeness of the Unit 3 soil. Bingham will deliver the groundwater samples to a State-Certified laboratory for analysis of the groundwater. Bingham will analyze the results from the groundwater analysis to determine if the groundwater is representative of site conditions. Bingham will ship the groundwater and soil materials to Controls for Environmental Pollution, Inc. (CEP), located in Santa Fe, New Mexico, who will prepare the contact solution and perform batch and analytical testing on the contact solution and soil. CEP will also be responsible for procuring radionuclide material for the tests and disposal of the contact solution and soil used in the testing. Bingham will oversee all testing; review the quality control for the preparation and analytical testing of the contact solution; and prepare a report summarizing the results.

SECTION 2

APPROACH

2.1 GENERAL

An important parameter that significantly influences groundwater transport of a particular contaminant is it's K_d value. The K_d value is the ratio of the concentration of the contaminant absorbed to solid material to the concentration in solution, and provides an indication of how rapidly the contaminant can move relative to the rate of groundwater. The lower the K_d, the more mobile the contaminant. Site specific K_d values for the LARW site have not been determined in the past: therefore; the lowest value reported in literature under varying conditions has been used. For most elements this has resulted in very conservative K_d assumptions. For instance, the K_d range for Uranium is 0.1 to 1,000,000. The value used in contaminant transport modelling was 0.1, which is 7 orders of magnitude smaller than the largest reported K_d value. K_d values for selected radionuclides will be determined under conditions similar to actual field conditions.

K_d values are dependent on several factors, including soil type and groundwater chemistry. Soil and groundwater conditions that promote the adsorption of the contaminant to the soil, resulting in lower concentrations in the water, result in high K_d values. Typically the K_d value for a clay soil is larger than for a sandy soil due to the increased surface area, and the electrical charge on the clay particles which tend to attract the nuclides. The pH and redox potential (Eh) of the groundwater also affects contaminant mobility due to their effects on adsorption of the radionuclide.

The K_d tests will be performed under conditions typical of the shallow aquifer under the LARW waste cell. Unit 3 sand material will be collected and will be used in the K_d tests. Groundwater from the site will also be collected, and spiked with the radionuclides in order to manufacture a contact solution for the tests. The contact radionuclide tests will be performed over a range of concentrations predicted by previous contaminant transport modelling (RCT, 1993).

2.2 CRITICAL CONTAMINANTS

K_d tests will be performed on selected "critical contaminants". Critical contaminants are those contaminants which have an assumed K_d that is very low, and therefore have very low retardation rates resulting in high mobility in groundwater. Another factor to consider in choosing critical contaminants is the range of K_d values reported for the contaminant in literature. If the contaminant has a large range of K_d values, there is a good possibility of defining a site-specific K_d that is significantly larger than the assumed value. Listed below are the contaminants that are proposed for K_d testing.

TABLE 2.1 CRITICAL CONTAMINANTS

CONTAMINANT	TIME TO EXCEED PROTECTION LEVELS	RANGE OF Kd's
C-14	670 (1)	0.01 (3)
I-129	760 (1)	0.2 - 1.5 (4)
Np-237	900 (1)	0.2 - 400 (4)
Tc-99	570 (1)	0.001 - 400 (4)
Uranium	1040 (2)	0.1 - 1,000,000 (3)

Notes and References:

(1) These elements are contained in the mobile-waste subcell (See the RCT)

(2) This is based on a soil-weighted K_d value in the unsaturated zone

(3) Looney, B.B., M.W. Grant, and C.M. King, *Estimation of Geochemical Parameters for Assessing Subsurface Transport at the Savannah River Plant*, E.I. du Pont De Nemours & Co., Environmental Information Document, DPST-85-904, March 1987.

(4) Sheppard, M.I., D.I. Beals, D.H. Thibault, and P. O'Conner, *Soil Nuclide Distribution Coefficients and Their Distributions*, Atomic Energy of Canada Limited, AECL-8364, December 1984.

2.3 FACTORS INFLUENCING K_d VALUES

K_d values are influenced by both soil types and groundwater conditions. Soil and groundwater materials proposed to be used in the K_d tests will be collected from the site. The Unit 3 soil and groundwater has been sampled and analyzed extensively; results are presented in the *Geohydrologic Report* (Bingham, 1991). Listed below are factors influencing K_d values and how they will be accounted for in testing.

2.3.1 Soil Type

Unit 3 sand material collected from the LARW cell (See Figure 1) will be the soil used in the K_d tests. The majority of the transportation of the radionuclides occurs in this layer because the groundwater level is typically within this strata, and the water velocities are higher in the sand layer than the clay layer.

2.3.2 Contact Solution Radionuclide Concentrations

The contact solution is the radionuclide-contaminated water that is added to the Unit 3 soil used to perform the K_d tests. The contact solution is intended to duplicate expected groundwater conditions under the LARW disposal cell, due to the release of leachate into the groundwater. The K_d tests will be performed over a range of contact solution radionuclide concentrations that should encompass the range of expected groundwater concentrations. The maximum concentration, based on maximum permitted waste concentrations, will be used as the upper range of the radionuclide concentrations. Tests will be performed at two other concentrations; at 1/2 of the maximum concentration, and at the concentration typical of laboratory K_d testing. The three tests will be used to develop a graph of concentration in the solid phase vs. concentration in the liquid phase.

2.3.3 Contact Solution pH

The K_d for a particular contaminant is sensitive to the pH of the water/soil matrix. Generally the lower the pH the smaller the K_d value and the greater the mobility. There is the potential for low pH leachate to be produced from certain waste material disposed in the cell. The pH of the existing groundwater at the site typically ranges from neutral to slightly basic.

The pH of the existing groundwater is predicted to be insensitive to the application of a low-pH leachate, due to the large buffering capacity of the existing soil and groundwater. The buffering capacity is the result of a very high concentration of bicarbonate and carbonates in the groundwater and soil. Liner compatibility tests were performed on the silty clay soils at the site (Bingham, 1994); the pH of the leachate varied from 2 to 7. The leachate was passed through a compacted clay sample to determine how the leachate affected the hydraulic conductivity of the clay liner. In the tests, the leachate that percolated through the soil was buffered and the effluent pH was above 7 in all cases.

The pH of the contact solution for the K_d tests will be the same pH value as the composite water sample from the three wells. This should accurately duplicate actual field conditions due to the pH of the groundwater having little variability over the LARW area. Also, the pH of the site groundwater is predicted to be minimally affected by the addition of potentially low pH leachate, due to the buffering capacity of the groundwater and the dilution of the leachate within the groundwater.

2.3.4 Contact Solution Eh

The K_d for a particular contaminant is also sensitive to the Eh of the water/soil matrix. Because of the existing high salinity and total dissolved solids in the water, the Eh of the groundwater is believed to be minimally impacted due to the addition of the leachate into the groundwater. In addition to the high salinity and TDS of the groundwater, the leachate will be significantly diluted across the depth of the saturated Unit 3 soil. The Eh of the contact solution will be the same Eh value as the groundwater composited from the three wells.

2.4 TEST METHOD

The test that will be performed to determine K_d values is ASTM method D 4319-83, *Standard Test Method for Distribution Ratios by the Short-Term Batch Method.* The steps of the test are summarized below:

- Site-specific groundwater and soil samples will be collected and it will be demonstrated that the samples are representative of the LARW site.
- Contact solution consist of the site groundwater with varying radionuclide concentrations added.
- The contact solution will be applied to the soil.
- Following testing protocol times, the contact solution will be decanted from the soil.
- The soil and contact solution will be analyzed to determine K_d values.
- The results will be summarized and reported by Bingham.

Test conditions are designed to ensure that the K_d value is realistic and reasonably conservative for variations in both the soil, and the leachate generated from the disposal cell. Using groundwater and soil from the site will minimize the variability between laboratory derived K_d values and actual field values.

SECTION 3

MATERIAL PROGRAM

3.1 MATERIAL COLLECTION

Materials used in K_d testing will be Unit 3 sand and groundwater from the LARW site, in order to replicate site conditions to the best extent possible. Soil and groundwater will be collected from the site by Envirocare and will be delivered to Bingham Laboratory, for analysis and preparation for shipment to the analytical laboratory.

3.1.1 Unit 3 Sand

The sand material proposed for performing the K_d tests will be representative material from the Unit 3 layer at the Clive site. The soil will be collected by Envirocare from three (3) locations, see Figure 1. The majority of the overlying Unit 4 clay has already been excavated in the soil sampling area, to be used as liner and cover material for the LARW cell. The Unit 3 sand is therefore expected to be within 2 feet of the bottom of the existing excavation in the soil sampling area. If the Unit 3 sand is exposed in this area, the soil sample should be collected from at least 1 foot below the surface. The material will be visually inspected at the time of collection to verify the material is Unit 3 sand. The material will be identified by location, placed in a labeled and sealed 5 gallon bucket, and transported to the Bingham Material Laboratory by Envirocare personnel. The amount collected will be approximately 75 kgs. (one moderately packed 5 gallon bucket per location) for a total of 15 gallons. The soils will be tested and the characteristics of the collected material will be compared to existing Unit 3 data to ensure the material is representative of Unit 3 soils. Extensive data exists for the Unit 3 sand and is presented in the *Hydrogeological Report* (Bingham, 1991).

3.1.2 Groundwater

Groundwater from the Clive site will be collected and used as the contact solution for the K_d test. The groundwater will be collected from three wells; GW-20, GW-22, and GW-64. The wells are located around the perimeter of the LARW cell. The groundwater will be composited at the analytical laboratory that is performing the K_d tests to achieve a groundwater that is representative of site conditions. The material will be collected by Envirocare by pumping water from the wells. Three well casings will be removed from the well prior to collection of the sample to ensure that the water is representative of groundwater in the soil. Groundwater analytical samples will also be collected at this time (See Section 3.2). The groundwater for the K_d tests will be placed in clean 5 gallon containers, provided by the laboratory that is performing the groundwater analytical tests, and transported to the Bingham Material Laboratory by Envirocare personnel. The contact solution amount collected will be at least 5 gallons per well, for a total of 15 gallons. The groundwater will be analyzed and compared to existing chemistry data for the groundwater at the site.

3.2 MATERIAL ANALYSIS

The soil and groundwater will be analyzed prior to performing the K_d tests to ensure that the materials are representative of site conditions. The characteristics of the collected soil and groundwater will be compared to existing data for the Unit 3 soil and the groundwater.

3.2.1 Soil Analysis

Extensive previous laboratory testing has been performed for Unit 3 soil material. The soil has been characterized as a tan silty sand material. The Unit 3 material has been shown to be quite homogenous across the site in both gradation and chemistry. Bingham laboratory will perform grain size distribution curves on the three soil samples to determine if the soil is typical of Unit 3 soils.

3.2.2 Groundwater Analysis

Extensive laboratory testing has been performed for groundwater at the Clive site. The groundwater has been classified as a Class IV groundwater (saline groundwater) due to elevated levels of TDS. All analytical tests presented in Table 5.1 will be performed on the groundwater prior to shipping to CEP to determine if the sample is representative of the shallow aquifer.

SECTION 4

ANALYTICAL LABORATORY PROGRAM

4.1 TEST SUMMARY

The test method that is used to determine K_d values, ASTM method D 4319-83 *Standard Test Method for Distribution Ratios by the Short-Term Batch Method*, specifies that the tests are to be performed in triplicate. The three tests are required to have separate contact periods (soil mixed with the contact solution) of between 3 to over 14 days. The K_d for the particular radionuclide at a given concentration is the average of the K_d values from the three contact periods. The laboratory will provide K_d values for all three contact periods and Bingham will evaluate these results to determine the average and variability of the data from the three tests. The K_d tests are presented in Table 4.1 below.

TABLE 4.1 SUMMARY OF BATCH TESTS

TEST ID #	RADIONUCLIDE	CONTACT SOLUTION CONCENTRATION (pCi/l)
1	C-14	500,000
2	C-14	250,000
3	C-14	10,000
4	I-129	250,000
5	I-129	125,000
6	I-129	10,000
7	Np-237	150,000
8	Np-237	75,000
9	Np-237	5,000
10	Tc-99	600,000
11	Tc-99	300,000
12	Tc-99	20,000
13	U (natural)	20,000,000
14	U (natural)	10,000,000
15	U (natural)	40,000

The development of the contact solution concentrations is presented below.

4.2 CONTACT SOLUTION GENERATION

The contact solution will be prepared by a certified laboratory in accordance with conditions determined by Bingham to be representative of groundwater conditions under the LARW disposal cell.

4.2.1 Procedure

Water used as a base for generation of the contact solution will be groundwater from the site. After the groundwater is determined to representative, the water will be shipped to CEP to use as a base for preparing the contact solution. Radionuclide material will be added to the groundwater to model the discharge of contaminated leachate into the groundwater. The contact solution for each test will contain one radionuclide species only, in order to limit interference during analysis of the soil and decanted contact solution.

4.2.2 Concentrations

Maximum permitted waste concentrations have been developed from contaminant transport modelling presented in the RCT. Based on these waste concentrations, unsaturated PATHRAE modelling predicts leachate concentrations. The contact solution concentrations are derived from these maximum peak leachate concentrations predicted by PATHRAE. The maximum leachate concentrations are modified to account for the effects of dilution within the groundwater.

Based on an infiltration rate of 2.47 cm/yr; a aquifer velocity of 0.087 m/yr; and an assumed aquifer mixing depth of 1 foot; the leachate from the disposal cell is diluted in the groundwater by a factor of 5. Maximum leachate and contact solution concentrations are presented below.

TABLE 4.2 MAXIMUM CONCENTRATIONS

CONTAMINANT	LEACHATE (1) (pCi/l)	DILUTION FACTOR	PROPOSED CONTACT SOLUTION (pCi/l)
C-14	2,430,000	5	500,000
I-129	1,210,000	5	250,000
Np-237	780,000	5	150,000
Tc-99	2,950,000	5	600,000
Uranium	100,000,000	5	20,000,000

(1) From PATHRAE modelling (RCT, 1993)

Using the maximum leachate concentrations from PATHRAE should result in conservatively high contact solution concentrations, because the maximum concentration is a peak value that is not sustained over time. Also, after the leachate has traveled in the groundwater for any significant length the leachate will be diluted due to the addition of groundwater and the effects of dispersion and diffusion.

4.3 ANALYTICAL TESTING

A total of fifteen (15) batch tests will be performed utilizing the radionuclide-spiked contact solutions shown in Table 4.2. The soil and contact solution will be analyzed to determine the concentration of the particular radionuclide in both the soil and in the contact solution. Based on these concentrations, a K_d value for the radionuclide will be calculated. Results from the tests will be reviewed by Bingham to determine if QA/QC guidelines were met.

SECTION 5

QUALITY ASSURANCE OBJECTIVES

5.1 OBJECTIVE

The objective of the QA plan is to assure that results from K_d testing are accurate and representative of site conditions. Quality controls must be in place for both; (1) materials - Unit 3 sand and groundwater and, (2) testing procedures. Values that are used in future contaminant transport modelling must be representative of actual K_d values that will be seen in the field.

5.2 ANALYTICAL METHODS

Groundwater chemistry will be determined by analyzing for macro constituents; cations and anions; pH; and Eh. The groundwater then will be used to manufacture the contact solution. Detection limits required for analysis of the groundwater are:

TABLE 5.1 GROUNDWATER CHARACTERIZATION ANALYTICAL TESTS

PARAMETERS	REQUIRED EPA METHOD No.	REQUIRED DETECTION LIMITS (mg/l)	MAXIMUM HOLDING TIMES
CATIONS/ANIONS(mg/l)			
Bicarbonate	310.1	10	14 Days
Carbonate	310.1	10	14 Days
Chloride	325.3	1.0	28 Days
Sulfate	375.4	0.5	28 Days
Calcium	6010	0.01	6 Months
Magnesium	6010	0.01	6 Months
Potassium	6010	0.01	6 Months
Sodium	6010	0.01	6 Months
OTHER			
Total Dissolved Solids	160.1	10	7 Days
pH (1)	150.1	0.1	
Eh (1)	2580		

(1) To be measured in the field and immediately upon arrival to the laboratory

The contact solution used in the K_d testing will be manufactured to Bingham's specifications for radionuclide concentrations. Detection limits required for analysis of the contact solution are:

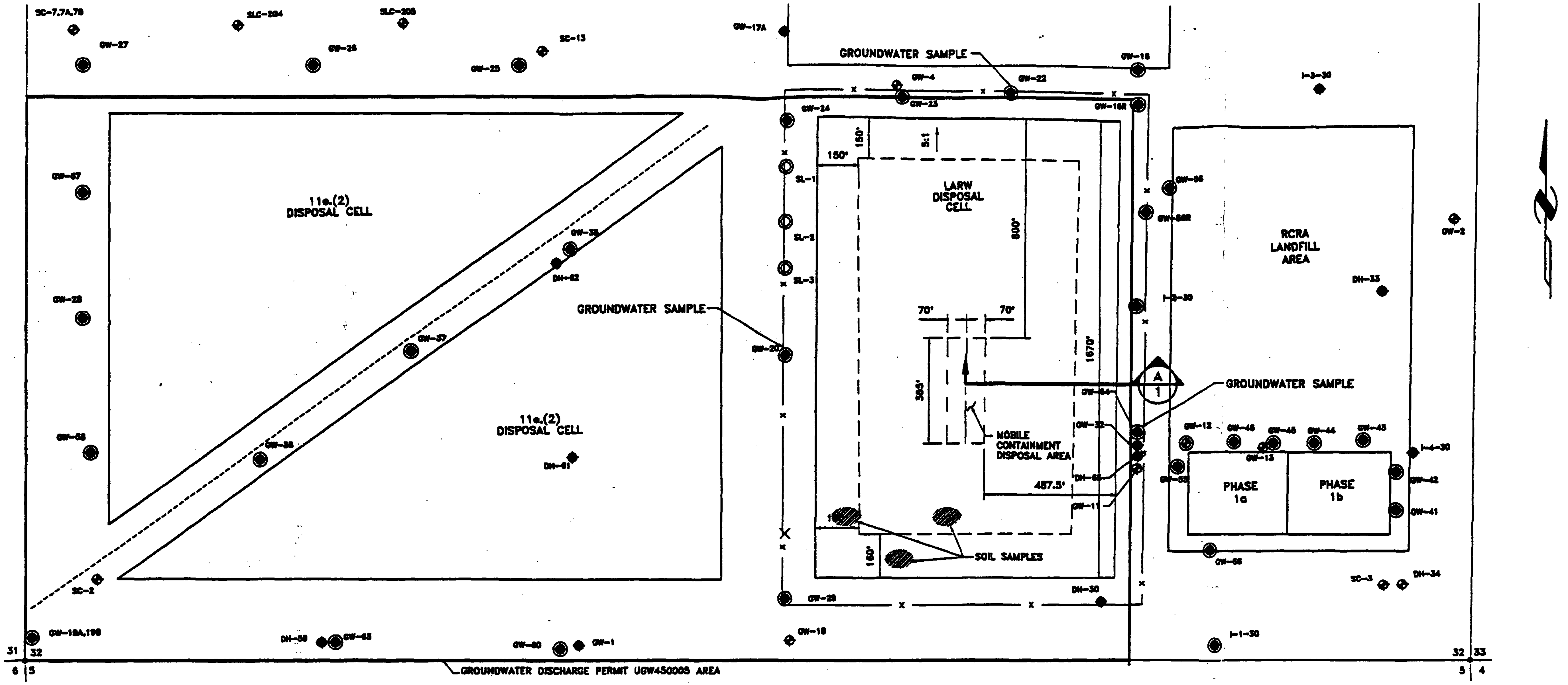
TABLE 5.2 CONTACT SOLUTION ANALYTICAL TESTS

PARAMETERS	REQUIRED EPA METHOD No.	REQUIRED DETECTION LIMITS (mg/l)	MAXIMUM HOLDING TIMES
RADIONUCLIDES			
C-14	EPA C-01	215 pCi/l	6 Months
I-129	EPA 902.0	1 pCi/l	6 Months
Np-237	EPA 907.0	1 pCi/l	6 Months
Tc-99	HASL 300	80 pCi/l	6 Months
Uranium (total)	ASTM 2907-83B	0.7 pCi/l	6 Months

SECTION 6

DISPOSAL OF CONTAMINATED MATERIAL

All analytical radionuclide testing of soil and contact solution will be performed by CEP. All contaminated equipment and clothing will be collected and disposed of in an approved method. Disposal of all radioactive material and equipment will be performed by CEP. A record of disposal and a record of transfer will be sent to Bingham and retained in our files, with proof of license authority by the recipient. All transporting of licensed material to a carrier for transport will be done in accordance with the provisions of Title 10, code of Federal Regulations, Part 71, "Packaging for Radioactive Material for Transport and Transportation of Radioactive Material Under Certain Conditions.

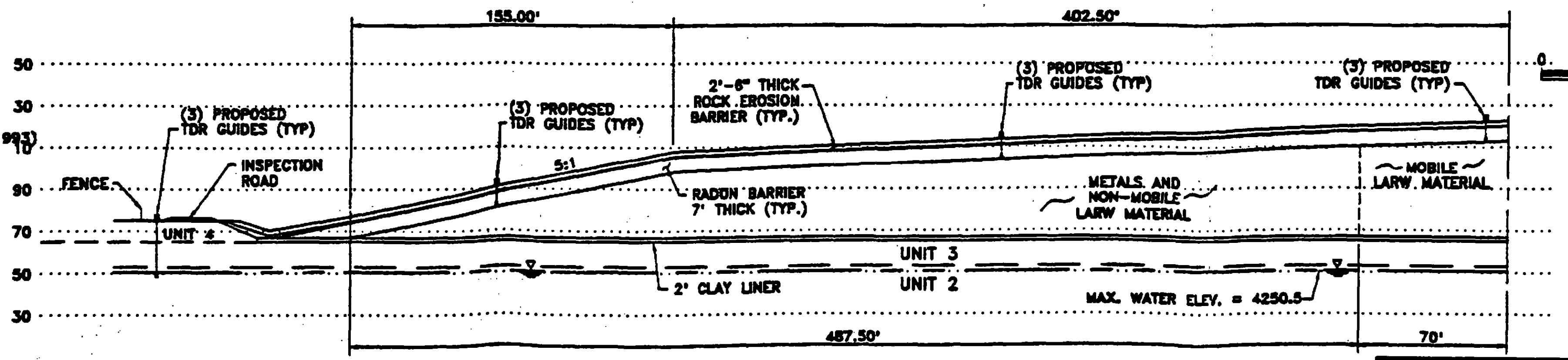


LEGEND

◈	GW-16 Through GW-63	Monitor Wells–Bingham Environmental (1991–1993)
◈	DH-30 Through DH-62	Exploratory Holes / Piezometers–Bingham Environmental (1991–1993)
◈	I and other GW's:	Delta Geotechnical Consultants (1988,1990)
◈	SLC-	Jacobs Engineering Group, Inc. (1984)
◈	SC-	Dames & Moore (1981–1982)
◉		Monitor Wells Included In Network
⊕		Suction Lysimeters To Be Installed In Network

SOIL SAMPLING CODE

◆	Continuous Soil Sampling Hole
◈	Discontinuous Soil Sampling Hole



SECTION A/1

0 40 80
Scale In Feet

ENVIROCARE OF UTAH

DISTRIBUTION RATIO TESTING

SOIL AND GROUNDWATER SAMPLING LOCATIONS

BINGHAM ENVIRONMENTAL
SALT LAKE CITY – (801) 532-2230

FIGURE 1

Rev.	By	Date	Remarks	Date MARCH 1995	Proj. # 2019-013	DAN

APPENDIX B

ASTM METHOD D 4319-83

Designation: D 4319 – 83

Standard Test Method for Distribution Ratios by the Short-Term Batch Method[1]

This standard is issued under the fixed designation D 4319; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

As an aqueous fluid migrates through geologic media, certain reactions occur that are dependent upon the chemistry of the fluid itself and upon the chemistry and geochemistry of other fluids and solid phases with which it comes in contact. These geochemical interactions determine the relative rates at which chemical species in the migrating fluid (such as ions) travel with respect to the advancing front of water. Processes of potential importance in retarding the flow of chemical species in the migrating fluid (movement of species at velocities less than the ground-water velocity) include ion exchange, adsorption, complex formation, precipitation (or coprecipitation, for example Ba^{++} and Ra^{++} co-precipitating as the sulfate), oxidation-reduction reactions, and precipitate filtration. This test method applies to situations in which only sorptive processes (adsorption and ion exchange) are operable for the species of interest, however, and is restricted to granular porous media.

It is difficult to derive generalized equations to depict ion exchange-adsorption reactions in the geological environment. Instead, a parameter known as the *distribution coefficient* (K_d) has been used to quantify certain of these sorption reactions for the purpose of modeling (usually, but not solely, applied to ionic species). The distribution coefficient is used to assess the degree to which a chemical species will be removed from solution as the fluid migrates through the geologic media; that is, the distribution coefficient provides an indication of how rapidly an ion can move relative to the rate of ground-water movement under the geochemical conditions tested.

This test method is for the laboratory determination of the *distribution ratio* (R_d), which may be used by qualified experts for estimating the value of the distribution coefficient for given underground geochemical conditions based on a knowledge and understanding of important site-specific factors. It is beyond the scope of this test method to define the expert qualifications required, or to justify the application of laboratory data for modeling or predictive purposes. Rather, this test method is considered as simply a measurement technique for determining the distribution ratio or degree of partitioning between liquid and solid, under a certain set of laboratory conditions, for the species of interest.

Justification for the distribution coefficient concept is generally acknowledged to be based on expediency in modeling-averaging the effects of attenuation reactions. In reference to partitioning in soils, equilibrium is assumed although it is known that this may not be a valid assumption in many cases. Equilibrium implies that (*1*) a reaction can be described by an equation and the free energy change of the reaction, within a specific system, is zero, and (*2*) any change in the equilibrium conditions (T, P, concentration, etc.) will result in immediate reaction toward equilibrium (the concept is based upon reversibility of reactions). Measured partitioning factors may include adsorption, coprecipitation, and filtration processes that cannot be described easily by equations and, furthermore, these solute removal mechanisms may not instantaneously respond to changes in prevailing conditions. Validity of the distribution coefficient concept for a given set of geochemical conditions should not be assumed initially, but rather should be determined for each situation.

This is a short-term test and the attainment of equilibrium in this laboratory test is not presumed, although this may be so for certain systems (for example, strictly interlayer ion exchange reactions of clays). Consistent with general usage, the result of this test could be referred to as "distribution coefficient" or as "distribution ratio;" in the strictest sense, however, the term "distribution ratio" is preferable in that the attainment of equilibrium is not implied.

The distribution ratio (R_d) for a specific chemical species may be defined as the ratio of the mass

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[1] This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.14 on Geotechnics Management.

Current edition approved Nov. 28, 1983. Published January 1984.

sorbed onto a solid phase to the mass remaining in solution, which can be expressed as:

$$R_d = \frac{\text{(mass of solute on the solid phase per unit mass of solid phase)}}{\text{(mass of solute in solution per unit volume of the liquid phase)}}$$

The usual units of R_d are mL/g (obtained by dividing g solute/g solid by g solute/mL solution, using concentrations obtained in accordance with this test method).

Major difficulties exist in the interpretation, application, and meaning of laboratory-determined distribution ratio values relative to a real system of aqueous fluid migrating through geologic media.[2] Typically, only reactions between migrating solutions and solid phases are quantified. In general, geochemical reactions that can result from interaction of the migrating fluid with another aqueous phase of a differing chemistry have not been adequately considered (interactions with other liquids can profoundly change the solution chemistry). Additionally, as noted above, the distribution coefficient or K_d concept implies an equilibrium condition for given reactions, which may not realistically apply in the natural situation because of the time-dependence or kinetics of specific reactions involved. Also, migrating solutions always follow the more permeable paths of least resistance, such as joints and fractures, and larger sediment grain zones. This tends to allow less time for reactions to occur and less sediment surface exposure to the migrating solution, and may preclude the attainment of local chemical equilibrium. Thus, the distribution coefficient or K_d concept is only directly applicable to problems involving contaminant migration in granular porous material.

Sorption phenomena are also strongly dependent upon the thermodynamic activity of the species of interest in solution (chemical potential). Therefore, experiments performed using only one activity or concentration of a particular chemical species may not be representative of actual in situ conditions or of other conditions of primary interest. Similarly, unless experimental techniques consider all ionic species anticipated to be present in a migrating solution, adequate attention is not directed to competing ion and ion complexation effects, which may strongly influence the R_d for a particular species.

Many "sorption" ion complexation effects are strongly influenced, if not controlled, by conditions of pH and Eh. Therefore, in situ conditions of pH and redox potential should be considered in determinations of R_d. To the extent possible, these pH and Eh conditions should be determined for field locations and must be approximated (for transition elements) in the laboratory procedure.

Other in situ conditions (for example, ionic strength, anoxic conditions, or temperature) could likewise have considerable effect on the R_d and need to be considered for each situation. Additionally, site-specific materials must be used in the measurement of R_d. This is because the determined R_d values are dependent upon rock and soil properties such as the mineralogy (surface charge and energy), particle size distribution (surface area), and biological conditions (for example, bacterial growth and organic matter). Special precautions may be necessary to assure that the site-specific materials are not significantly changed prior to laboratory testing.

The choice of fluid composition for the test may be difficult for certain contaminant transport studies. In field situations, the contaminant solution moves from the source through the porous medium. As it moves, it displaces the original ground water, with some mixing caused by dispersion. If the contaminant of interest has an R_d of any significant magnitude, the front of the zone containing this containment will be considerably retarded. This means that the porous medium encountered by the contaminant has had many pore volumes of the contaminant source water pass through it. The exchange sites achieve a different population status and this new population status can control the partitioning that occurs when the retarded contaminant reaches the point of interest. It is recommended that ground water representative of the test zone be used as contact liquid in this test; concentrations of potential contaminants of interest used in the contact liquid should be judiciously chosen. For studies of interactions with intrusion waters, the site-specific ground water may be substituted by liquids of other compositions.

The distribution ratio for a given chemical species generally assumes a different value when any of the above conditions are altered. Clearly, a very thorough understanding of distribution coefficients and the site-specific conditions that determine their values is required if one is to confidently apply the K_d concept (and the measured R_d values) to migration evaluation and prediction.

The adoption of a standard method for determining distribution ratios, R_d, especially applicable for ionic species, is important in that it will provide a common basis for comparison of

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[2] Coles, D. G., and Ramspott, L. D., "Migration of Ruthenium-106 in a Nevada Test Site Aquifer: Discrepancy Between Field and Laboratory Results," *Science*, Vol. [illegible] pp. 1235–1237, March 5, 1982.

experimental results (particularly for near-similar conditions).

The most convenient method of determining R_d is probably the *batch method* (this test method), in which concentrations of the chemical species in solid and liquid phases, which are in contact with one another, are measured with time. Other methods include the dynamic test or column flow-through method using (*1*) continuous input and (*2*) pulsed input, the in situ dual tracer test, and the thin-layer chromatography (TLC) test.

In summary, this distribution ratio, R_d, is affected by many variables, all of which may not be adequately controlled or measured by the batch method determination. The application of experimentally determined R_d values for predictive purposes (assuming a functional relationship such as $R_d = K_d$) must be done judiciously by qualified experts with a knowledge and understanding of the important site-specific factors. However, when properly combined with knowledge of the behavior of chemical species under varying physicochemical conditions of the geomedia and the migrating fluid, distribution coefficients (ratios) can be used for assessing the rate of migration of chemical species through a saturated geomedium.

1. Scope

1.1 This test method covers the determination of distribution ratios of chemical species for site-specific geological media by a batch sorption technique. It is a short-term laboratory method primarily intended for ionic species subject to migration in granular porous material, and the application of the results to long-term field behavior is not known. Distribution ratios for radionuclides in selected geomedia are commonly determined for the purpose of assessing potential migratory behavior at waste repositories. This test method is also applicable to studies of intrusion waters and for parametric studies of the effects of variables and of mechanisms which determine the measured distribution ratios.

1.2 The values stated in acceptable metric units are to be regarded as the standard.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 422 Method of Particle-Size Analysis of Soils[3]

D 2217 Practice for Wet Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants[3]

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[3]

D 3370 Practices for Sampling Water[4]

3. Description of Terms Specific to This Standard

3.1 *distribution coefficient, K_d*—is identically defined as R_d for equilibrium conditions and for ion exchange-adsorption reactions only. To apply R_d values to field situations, an assumption such that $R_d = K_d$ is necessary. The validity of such an assumption can only be determined by informed experts making a judgment (albeit uncertain) based on a detailed study of the specific site.

3.2 *distribution ratio, R_d*—the ratio of the concentration of the species sorbed on the soil or other geomedia, divided by its concentration in solution under steady-state conditions, as follows:

$$R_d = \frac{\text{(mass of solute on the solid phase per unit mass of solid phase)}}{\text{(mass of solute in solution per unit volume of the liquid phase)}}$$

by steady-state conditions it is meant that the R_d values obtained for three different samples exposed to the contact liquid for periods ranging from 3 to at least 14 days, other conditions remaining constant, shall differ by not more than the expected precision for this test method.

The dimensions of the expression for R_d reduce to cubic length per mass (L^3/M). It is convenient to express R_d in units of millilitres (or cubic centimetres) of solution per gram of geomedia.

3.3 *species*—a distinct chemical entity (such as an ion) in which the constituent atoms are in specified oxidation states

4. Significance and Use

4.1 The distribution ratio, R_d, is an experimentally determined parameter representing the distribution of a chemical species between a given fluid and a geomedium sample under certain conditions, including the attainment of a steady state. Based on a knowledge and understanding of the important site-specific factors, R_d values may be used by qualified experts for estimating the value of the distribution coefficient, K_d, for a given set of underground geochemical conditions. The K_d concept is used in mass transport modeling, for example, to assess the degree to which an ionic species will be removed from solution as the solution migrates through the geosphere. For applications other than transport modeling, batch R_d measurements also may be used, for example, for parametric studies of the effects of variables and of mechanisms related to the interactions of fluids with geomedia.

5. Apparatus

5.1 *Laboratory Ware* (plastic bottles, centrifuge tubes, open dishes, pipets, graduates), cleaned in a manner consistent with the analyses to be performed and the required precision. Where plateout may have significant effect on the measurement, certain porous plastics should be avoided and

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[3] *Annual Book of ASTM Standards*, Vol. 04.08.

[4] *Annual Book of ASTM Standards*, Vol. 11.01.

u[illegible] of FEP TFE-fluorocarbon containers is recom- nd[illegible].

.2 *Centrifuge*, capable of attaining 1400 g, or filtering paratus.

.3 [illegible]*aboratory Shaker/Rotator*, ultrasonic cleaner (op- nal[illegible]

.4 *Environmental Monitoring Instruments*, a pH meter, trometer and electrodes for Eh determination, conduc- ce[illegible]pparatus, and thermometer.

.5 [illegible]*nalytical Balance.*

.6 *Appropriate Equipment*, necessary to maintain in situ di[illegible]ons within the laboratory.

.7 [illegible]*nalytical Instrumentation*, appropriate for determi- ion of the concentration of major constituents (cations anions) and of the species of interest (for which R_d is ng[illegible]etermined) in the contact solutions (and, optionally, the[illegible]eomedia samples).

Sa[illegible]pling

6.1 [illegible]he samples of soil, rock, or sediment shall be sidered to be representative of the stratum from which it s obtained by an appropriately accepted or standard ce[illegible]re and based on expert judgment.

6.2 [illegible]he sample shall be carefully identified as to origin in ordance with Practice D 2488.

6.3 [illegible] geological description shall be given of the core te[illegible] used for the distribution ratio measurement, in- ding particle-size analysis (Method D 422) for uncon- idated material, depth of sample, and boring location.

6.4 [illegible]ampling of representative ground water in the test ne [illegible] use as the contact liquid in this test method shall be complished in accordance with Practices D 3370, using np[illegible]g devices that will not change the quality or environ- nt[illegible]conditions of the waters to be tested. Recommended thods include the use of Kemmerer samplers or inert gas ssure lifts (provided this does not alter the ground-water np[illegible]by stripping out carbon dioxide and raising the pH, ex[illegible]nple) or submersible diaphragm-type pumps. Proper cautions should be taken to preserve the integrity of in u conditions of the sampled water, and in particular to ote[illegible] against oxidation-reduction, exposure to light for ten[illegible]d periods, and temperature variation.

NOTE 1—It is recognized that sampling is likely to be a major oble[illegible]Materials (or fractures) that the contaminants pass through are ly [illegible]e the most difficult part of the geologic section to sample. In ition, proper sampling entails determining the path of ground-water so that the critical materials can be sampled. This determination is om[illegible]complished in sufficient detail in normal geologic site explo- on [illegible]grams, and, if it is attempted in some cases, the exploration gra[illegible]may become unacceptably expensive. Specific guidelines are ond the scope of this test method, however, it is recommended that logi[illegible]nd water sampling procedures be carefully considered by the on[illegible] involved in the site examination.

Procedure

7.1 [illegible]his test method can be applied directly to consoli- ted [illegible]re material samples or to disaggregated portions of core material samples. For the applications intended for is t[illegible] method, however, disaggregation of the samples is re[illegible]mmended procedure. Disaggregate the sampled soil d f[illegible]ble core materials (this may be done by ultrasonic method although it should be noted that the effect of ultrasonics on the microstructure of geological material may lead to higher sorption values in certain cases). If a sufficiently large-sized sample is available, separate 200-g portions through a "nonbias" riffle splitter. Crush competent sedimentary rock materials to a desired particle size or equivalent soil texture anticipated to result from natural weathering processes (this is because surface area is controlled by sample particle size).

NOTE 2—A significant source of error may be introduced by disaggregating the sample in a batch test in that (*a*) disaggregation can mask a preferred flow path (either horizontal or vertical), (*b*) disaggregation can destroy the effect of preferred flow paths caused by fractures or perhaps thin sand stringers, and (*c*) disaggregation will tend to increase the available surface area of the geologic materials. It is for the purpose of achieving uniformity of application, however, that disaggregation is recommended for this test method. It should be realized by persons applying results from this method that inclusion of the disaggregating operations may for these reasons tend to maximize the values of the distribution coefficients (ratios) obtained from this test method.

7.2 In some cases, it may be desirable to remove organic material from the geomedium (soil specimen) for comparative purposes. If this is so indicated, remove the organic material from the composite sample mixtures for selected samples by treatment with concentrated hydrogen peroxide (30 % H_2O_2), using the procedure given in "Soil Chemical Analysis."[5] In such a case, make duplicate runs using samples both with and without pretreatment to remove organics. It should be noted, however, that treatment with concentrated hydrogen peroxide could cause other changes in the geomedium, for example, dissolution of hydrous metal oxides that may be important adsorbents.

7.3 Using standard analytical procedures, characterize the geologic specimen (without pretreatment and, if so done, with the pretreatment to eliminate organics) as considered appropriate. The analyses may include percent chemical composition of anhydrous oxides (for example, SiO_2, FeO, MnO, CaO, Na_2O, etc.), hydrous oxides (for example, Fe, Mn, and Al hydrous oxides), and minerals that are present, and carbonate content, surface area (m^2/g), and cation and anion exchange capacity (at specified pHs). Similarly, characterize the contact liquid obtained from the test zone as appropriate for interpreting the results. Chemical analysis of the liquid should include macro constituents (for example, Na^+, Ca^{++}, K^+, Mg^{++}, Cl^-, $HCO_3^-/CO_3{=}$, SiO_2, etc.) and redox-active and hydrolyzable species such as Fe and Mn ions. Likewise, determine the pH and Eh of the contact liquid, as well as the concentration (if present) of the chemical species of interest. Specific instructions for the Eh determination are not part of this test method, however, use of a referenced technique is advised (such as a platinum versus standard calomel electrode measurement). If the species of interest may exist in the contact liquid in a variety of valence or chemical states (for example, with studies of actinides), a method of determining speciation should be applied.

7.4 Pass each of the soil and rock (core sediments) fractions again through a "nonbias" riffle splitter and place

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[5] Jackson, M., *Soil Chemical Analysis*, Prentice Hall, Englewood Cliffs, NJ, 1954.

four 5- to 25-g portions (record weight to nearest 0.1 g) in centrifuge tubes or bottles.

NOTE 3—Unless it is decided that the samples may be allowed to dry by exposure to the open air, record a moisture weight (for comparative purposes, a moisture content determination should be done with a separate sample). Some soils never dry in nature, and characteristics may be greatly altered when dried. This is especially true for originally anoxic sediments. If the samples are not to be allowed to dry before testing, follow Practice D 2217 (Procedure B) for maintaining a moisture content equal to or greater than the natural moisture content. In all cases, the contact liquid used in this test is the sampled ground water from the site test zone.

7.5 If a radiotracer or spiked stable tracer determination of the distribution ratio is desired, pretreat the composite samples with exact solution (contact liquid) used in the determination but without the tracer present. This solution will be either the site-specific ground water or a selected intrusion water. Wash the composite soil and rock samples four times with the pretreatment solution. For the first three washes, stir the mixtures of soil and rock and pretreatment solution several times over a 15-min period, allow to settle, centrifuge at 1000 g or more for 5 min, and decant off the wash. Apply the fourth wash for at least 24 h with occasional stirring, and again separate the wash from the composite sample by centrifugation and decantation as before.

7.6 It may be advisable to pre-equilibrate the treatment solution (contact liquid) with the geomedia prior to the start of this test method. Proceed as in 7.5, using the fourth wash after centrifugation and decantation as the treatment solution. Unless otherwise noted, add 20 to 100 mL (exact value should be equal to four times the weight in g of the geomedia) to each 100 to 250 mL centrifuge tube or bottle, and thoroughly mix the contents by stirring action. Prior to contact, the treatment solution should contain the species of interest at a known concentration prepared by the addition of chemically pure reagents to the site-specific ground-water sample. (The species of interest may be at trace concentration; if it is a radioactive or stable tracer added to the treatment solution, the elemental concentration as well as the isotopic concentration must be known.) If tracers are used, first equilibrate the tracer with the ground-water (or intrusion-water) sample by allowing to stand overnight and then filter using a ≤0.45 μm pore size membrane filter. Following this step, analyze the contact solution and add to the soil and rock composite samples as indicated above. Measure the pH of the soil/rock-solution system; if the pH has changed or if other than the natural pH is desired, adjust by addition of N NaOH solution or HCl, or by an appropriate buffer. The in situ Eh should be maintained, if necessary, under an inert atmosphere.

NOTE 4—Experiments have shown that R_d will vary depending on the solution-to-geomedium ratio used in the test. If other ratios are indicated (which would more closely approximate the normal field situation), duplicate runs should be made, however, the ratio prescribed here should also be run as the reference case. Because R_d varies with the solution/medium ratio, it is strongly recommended that this measurement include determination of the isotherm by making several runs with different ratios of solution-to-geomedium than specified above.

NOTE 5—Some analytical techniques may require larger volumes of sample fluid. Increased volume can be obtained by compositing samples or by scale-up using larger centrifuge tubes.

7.7 Determine the specific conductance of each solution and report in units of micromhos per centimetre at 20°C.

7.8 Run each set of samples at least in triplicate to demonstrate that steady state is attained in this short-term test. Stir the contents of each contact tube, then gently shake all of the soil/rock solution mixtures on a laboratory shaker/rotator for a minimum of 6 h for every 3-day portion of the contact period. The contact periods shall be for a minimum of 3 days, and the longest shall extend to 14 days or longer. The contact periods shall differ by at least a 3-day period. During the latter 1 or 2 days of the contact period allow all mixtures to stand and settle. If the variation of R_d with exposure time for these three or more contact periods is greater than the precision expected for this experiment, then the determination should be repeated for longer times until such a consistency is obtained. This is taken to be an indication that steady state has been established. In cases where the steady-state situation is not achieved, the extension of R_d values to the prediction of migratory behavior becomes of dubious value and requires clear reference to the inexactness of the application.

7.9 Measure and report the pH and Eh of all mixtures (in many investigations, pH and Eh will not vary greatly, so it might not be necessary to measure them on all samples).

7.10 Centrifuge each mixture for 20 min at a minimum setting of 1400 g. Controlled temperature centrifugation may be advised, particularly in the case of experiments run below ambient temperature. Carefully separate the phases. For the supernatant, the concentration of the species of interest can be directly determined using the appropriate standard analytical method.

7.11 If filtering is necessary or if desired for comparative purposes, use polycarbonate member filters (0.002 to 0.0 μm pore size), or the equivalent. Pretreat the filter disc by passing through it approximately 50 mL of 1.0 N HCl followed by 50 mL of distilled water, by gravity flow or suction to near dryness. Check the possibility of sorption of tracers onto the filter by a standard "double filter" technique using the original contact solution.

7.12 Filter the supernate from each soil/rock-solution mixture by gravity flow or suction to near dryness. Determine the concentration and speciation (chemical state), if it is variable, of the species of interest in this solution by the appropriate standard analytical method. Make a blank determination using the equivalent procedure outlined here (7.6 through 7.12, except do not add the soil/rock sample with treatment solution only. The use of tracers involves particular attention to corrections for blanks and potential plateout of the tracer on container walls, filters, and other surfaces as well as other losses. For example, it should be ascertained that loss of tracer to the blank vial walls is the same as for the walls of the sample vial, etc.

7.13 If necessary or if desired for comparative purposes or for a mass-balance determination, determine the concentration of the species of interest for each filtered solid residue. In this case, note the necessity of removing the residual solution from the solid phase, or correcting for it, particularly for solids with low R_d values. If this determination is made, a correction is required for the amount (if any) of the species of interest to be found naturally present in the soil/rock sample. Provided a satisfactory analysis is accomplished for the species concentration in the soil/rock residue, calculate R_d by dividing this value (g solute per g solid residue) by the final

TABLE 1 Example Calculation Sheet

The distribution ratio is given by:

$$R_d = \frac{(F_m)(V_s)}{(F_s)(W_m)}$$

where:

R_d = distribution ratio, mL/g,

F_s = fraction of total activity in solution, which equals the total concentration in solution, assuming the activity coefficients of a given ion were the same before and after steady state was attained in contact of the solution with the soil/rock materials (that is, the ionic strength is unchanged). Making this assumption, F_s is found by dividing the concentration of the ion *after* the solution has come to "equilibrium" (reaches steady state) with the soil/rock fraction by the concentration (of same units) of the ion *before* the solution was allowed to come to equilibrium with the soil fraction,

F_m = fraction of activity sorbed onto the mineral or solid residue (correcting for the natural content of the species of interest initially present), or, making the same assumption as to activity coefficients,

$$F_m = 1 - F_s$$

V_s = volume of solution "equilibrated" with W_m, mL, and

W_m = weight of mineral or solid residue, g.

In the case of a radioactive species of interest, where the radioactivities of the solution and solid residue are determined, the distribution coefficient is given by:

$$R_d = \frac{(A_m)(V_s)}{(A_s)(W_m)}$$

where:

A_m = activity of the mineral or solid residue, mCi, and

A_s = activity of the solution "equilibrated" with W_m, mCi.

concentration in the contact solution (g solute per mL solution), assuming the filter did not remove tracer from the solution. An alternative method is to compute R_d as shown on the Example Calculation Sheet (Table 1).

8. Precision and Bias

8.1 In following this method with usual care in analytical determinations, it is estimated that an overall precision or reproducibility of 10 to 25 % should be obtained. In many cases, this may be limited at very high or very low R_d values by the difficulty in measuring either very small residual concentrations or very small changes in a higher concentration. In such cases, constancy of R_d to within an order of magnitude may be acceptable for certain applications. It should be noted, however, that sampling difficulties and inability to properly measure or control the relevant in situ factors for determining the R_d of interest can inject a substantial uncertainty into the application of the obtained values in mass transport or solute modeling-predictive exercises.

TABLE 2 Example Report Sheet

Tabulated Results for Distribution Ratio Determination of Sample Number ________:
Contact liquid: Site-Specific Ground Water ________ Other (intrusion) Water ________ initial pH ________ initial Eh ______; method of determining Eh ________
final pH ________ final Eh ________________ temperature ________°C specific conductance ______________ µmhos/cm solid-to-liquid ratio ________ g/mL
contact time ______________ da equilibrating atmosphere ________ air ___________ other (specify) contact solution filtered after centrifugation? ________ yes
________ no disaggregated? ________ yes ________ no particle size ___________ mm H_2O_2 treatment to remove organics? ________ yes
________ no calculated dry weight of solid ________ g volume of contact liquid ________ mL species of interest ___________ method of analyzing for species of interest
____
____

(use separate sheet if necessary)

Site description, sampling methodology and core material description, analysis of core materials and of site-specific ground water or other contact liquid:

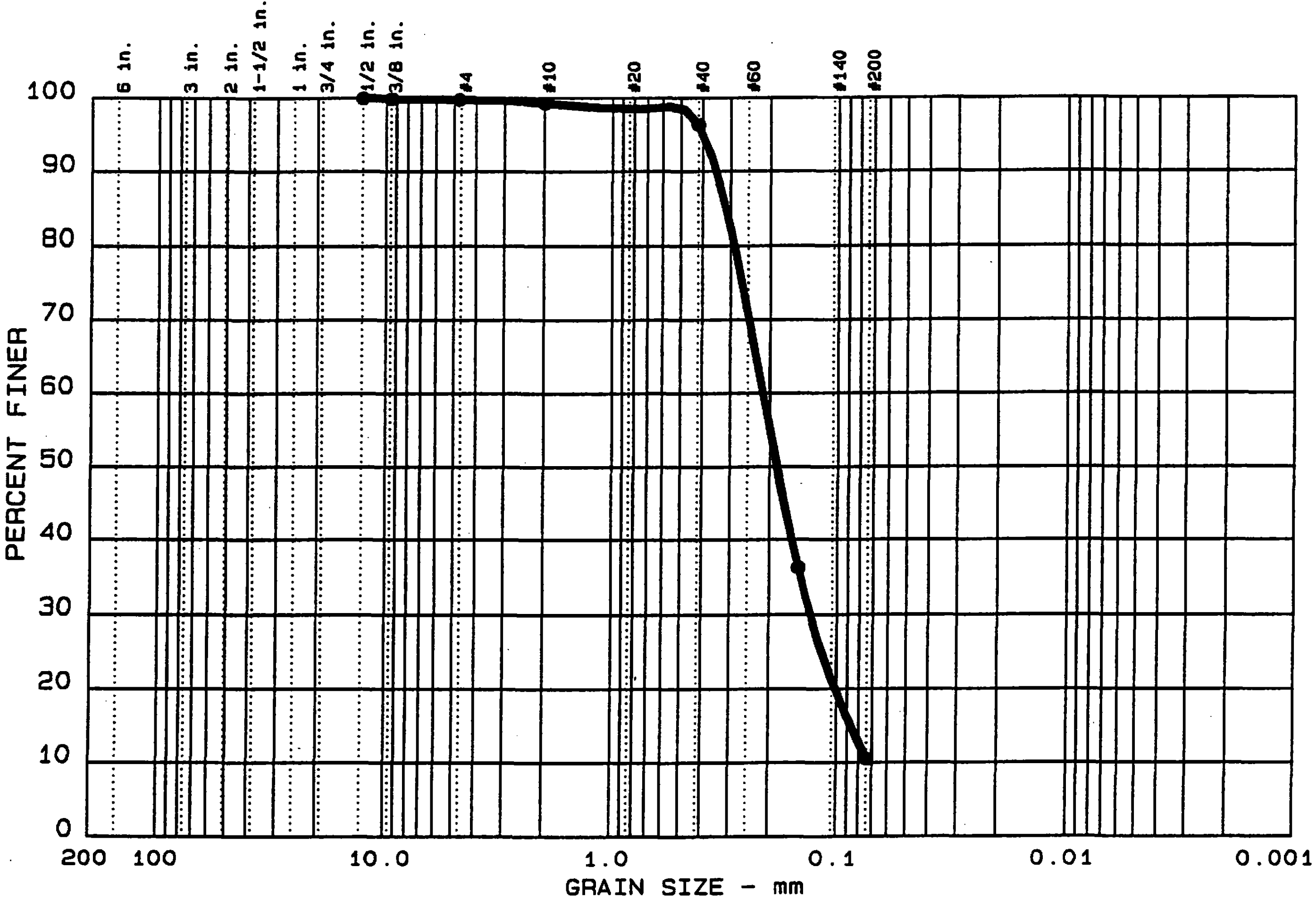
ATTACH SHEET

Species (Ion) of Interest	Initial Conc. in Solid (units)	Initial Conc. in Solution (units)	F_s F_m R_d	(mL/g)

APPENDIX C

SOIL TESTING

GRAIN SIZE DISTRIBUTION TEST REPORT



	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	0.2	89.3	10.5	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			0.32	0.21	0.19	0.132	0.0868			

MATERIAL DESCRIPTION	USCS	AASHTO
● Fine Sand W/Some Silt	SP-SM	A-3

Project No.: 2019-017
Project: Envirocare of Utah
● Location: KD Test Composite 1, 2, 3,

Date: 03-31-95

Remarks:

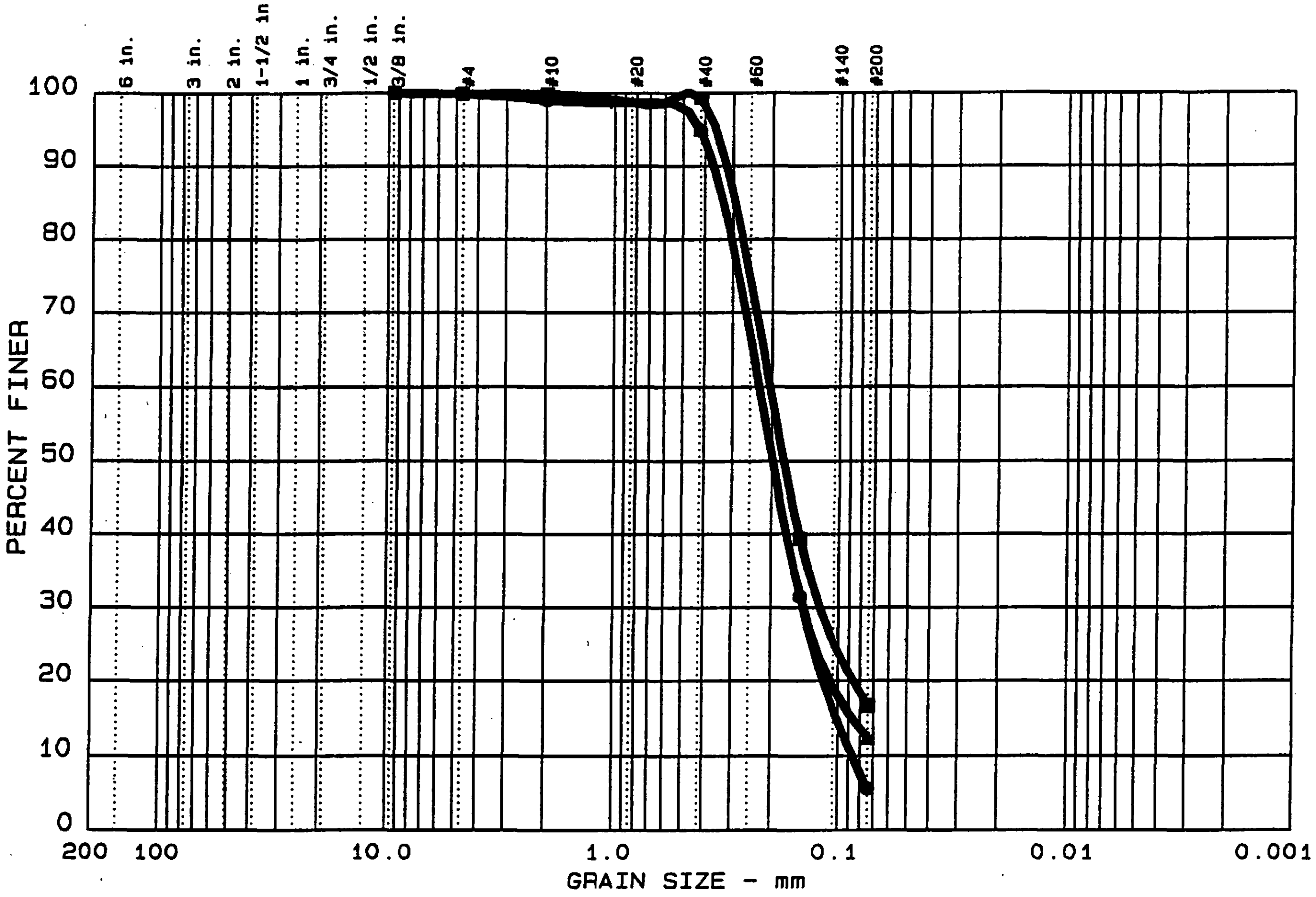
Tested By: DA

GRAIN SIZE DISTRIBUTION TEST REPORT

Bingham Engineering

Figure No.

GRAIN SIZE DISTRIBUTION TEST REPORT



	% +3"	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	0.1	94.4	5.5	
▲	0.0	0.1	87.6	12.3	
■	0.0	0.0	83.3	16.7	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			0.33	0.23	0.20	0.145	0.1014	0.0863	1.07	2.6
▲			0.33	0.23	0.20	0.144	0.0865			
■			0.29	0.20	0.18	0.121				

MATERIAL DESCRIPTION	USCS	AASHTO
● Fine Sand W/Some Silt	SP-SM	A-3
▲ Silty Fine Sand	SM	UNCLASSIFIE
■ Silty Fine Sand	SM	UNCLASSIFIE

Project No.: 2019-017
Project: Envirocare of Utah
● Location: KD Test #1
▲ Location: KD Test #2
■ Location: KD Test #3
Date: 03-31-95

Remarks:

Tested By: DA

GRAIN SIZE DISTRIBUTION TEST REPORT

Bingham Engineering

Figure No.

APPENDIX D

BARRINGER LABORATORY REPORT

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

7-Jun-95

David Cline
Bingham Environmental, Inc.
5160 Wiley Post Way
Salt Lake City, UT 84116

Attn: Received: 30-Mar-95 09:25
Project: COC 00107 PO #:

Job: 951671E Status: Final

ANALYTICAL REPORT PACKAGE

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

7-Jun-95
Page: i

David Cline
Bingham Environmental, Inc.
5160 Wiley Post Way
Salt Lake City, UT 84116

Attn: Received: 30-Mar-95 09:25
Project: COC 00107 PO #:

Job: 951671E Status: Final

CASE NARRATIVE

A total of 1 Water sample was received on 30-Mar-95. As stated in the chain of custody, the sample was run for the following analyses: Ca, Mg, K, Na, Alk-HCO3, Alk-CO3, Cl, SO4, TDS, pH and Redox. A table, to cross reference your sample ID to ours, is attached. Our procedures are summarized on the Quality Control Data Sheet. Each sample was extracted and analyzed within the proper holding times.

Quality control standards for organic and inorganic analyses followed the appropriate SW-846 or EPA methodology. Quality control standards for radiochemistry followed our standard operating procedures or contractual requirements.

Analyses were originally performed within holding times for pH, TDS and Alkalinity, but were reanalyzed outside holding time due to a client requested change order.

Signed: .... for Dave Lasher
Inorganic
Laboratory

Signed: C. E. Lott, Jr. ....
Project Review

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

7-Jun-95

David Cline
Bingham Environmental, Inc.
5160 Wiley Post Way
Salt Lake City, UT 84116

Attn:
Received: 30-Mar-95 09:25
Project: COC 00107
PO #:

Job: 951671E
Status: Final

Lab-ID	Matrix	Client Sample ID	Sampled
951671-5	Water	Composite 1 thru 3	NA

BARRINGER LABORATORIES INC.
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7-Jun-95
Page: R-1
Job: 951671E
Status: Final

Bingham Environmental, Inc.

Sample Id: Composite 1 thru 3
Lab Id: 951671-5 **Project: COC 00107**
Date Sampled: NA **Matrix: Water**

Analyte	Fraction	Method	Concentration	MDL	Date Analyzed
Calcium	Total	6010	400 mg/l	10	25-Apr-95
Magnesium	Total	6010	605 mg/l	5	25-Apr-95
Potassium	Total	6010	503 mg/l	250	25-Apr-95
Sodium	Total	6010	15400 mg/l	50	25-Apr-95
Alkalinity	HCO3	310.1M	243 mg/l	10	21-Apr-95
Alkalinity	CO3	310.1M	U mg/l	10	21-Apr-95
Chloride		300.0	23300 mg/l	1000	21-Apr-95
Sulfate		300.0	2550 mg/l	50	21-Apr-95
TDS		160.1	41500 mg/l	10	21-Apr-95
pH		150.1	7.52 unit	0.1	21-Apr-95
Redox		D1498	160 mV	1	21-Apr-95

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

7-Jun-95
Page: Q-1
Job: 951671E
Status: Final

Bingham Environmental, Inc.

QUALITY CONTROL REPORT

Sample Id	Calcium Total mg/l	Magnesium Total mg/l	Potassium Total mg/l	Sodium Total mg/l	Alkalinity HCO3 mg/l
Blank	U	U	U	U	NA
LCS (found)	21.4	21.1	20.6	21.1	2320
LCS (true)	20.0	20.0	20.0	20.0	2360
LCS % Rec	107	106	103	106	98.5
Duplicate	771	25.5	140	1840	243
Duplicate	758	25.1	139	1830	249
RPD	1.7	1.6	0.7	0.5	2.4
Spike % Rec	NA	NA	NA	NA	NA

Sample Id	Alkalinity CO3 mg/l	Chloride mg/l	Sulfate mg/l	TDS mg/l	pH unit
Blank	NA	U	U	U	---
LCS (found)	2320	19.0	39.7	1490	7.01
LCS (true)	2360	20.0	40.0	1480	7.00
LCS % Rec	98.5	95.0	99.2	100	100
Duplicate	U	34.8	90.7	23300	7.52
Duplicate	U	34.5	101	23300	7.56
RPD	---	0.9	10.8	0.0	0.5
Spike % Rec	NA	99.0	104	NA	---

Sample Id	Redox mV
Blank	---
LCS (found)	482
LCS (true)	475
LCS % Rec	101
Duplicate	160
Duplicate	170
RPD	5.7
Spike % Rec	---

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

7-Jun-95
Page: Q-2

David Cline
Bingham Environmental, Inc.
5160 Wiley Post Way
Salt Lake City, UT 84116

Attn:
Received: 30-Mar-95 09:25
Project: COC 00107
PO #:

Job: 951671E
Status: Final

Abbreviations:

Parameters:

TDS : Total Dissolved Solids
Redox : Oxidation-Reduction Potential

Methods:

HCO3 : Bicarbonate
CO3 : Carbonate

Units:

mg/l : milligrams per liter
mV : millivolts

Quality codes:

NA : Not Analyzed
U : Undetected

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

7-Jun-95
Page: Q-3

David Cline
Bingham Environmental, Inc.
5160 Wiley Post Way
Salt Lake City, UT 84116

Attn:
Project: COC 00107
PO #:
Received: 30-Mar-95 09:25

Job: 951671E
Status: Final

QUALITY CONTROL DATA SHEET

Received by: cs
Via: UPS

Sample Container Type: lg cu, 1l, bucket
Additional Lab Preparation: None

Parameter	Method	Preservative	Init	Analysis Dates
Ca	6010	HNO3	JH	04/25
Mg	6010	HNO3	JH	04/25
K	6010	HNO3	JH	04/25
Na	6010	HNO3	JH	04/25
Alk-HCO3	310.1M	4°C	RB	04/21
Alk-CO3	310.1M	4°C	RB	04/21
Cl	300.0	4°C	SP	04/21
SO4	300.0	4°C	SP	04/21
TDS	160.1	4°C	RB	04/21-04/24
pH	150.1	4°C	KT	04/21
Redox	D1498	4°C	AW	04/21

Barringer Laboratories, Inc. will return or dispose of your samples 30 days from the date your final report is mailed, unless otherwise specified by contract. Barringer Laboratories, Inc. reserves the right to return samples prior to the 30 days if radioactive levels exceed our license.

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

DISTRIBUTION RATIOS

RADIONUCLIDE____ I 129
PROPOSED ACTIVIT 10000 pCi/l
ACTUAL ACTIVITY__ 8052 pCi/l
(AFTER CONTACT EQUILIBRIUM)

ANALYSIS PERIOD_ 4/24/95 - 5/8/95
ANALYST PRESTON
CALCULATED BY________ DATE 5/23/95
CHECKED BY________ DATE 5-24-95
APPROVED BY________ DATE 6-6-95

i 129

HEAD SAMPLE	g IN SOL	UNCERTAINTY
10K	1.82E-06	1.17E-07

DAY	g OF SAND
3 DAY	10.0015
7 DAY	10.0015
14 DAY	10.002

DAY	g IN SOL	UNCERTAINTY	g ON SAND	UNCERTAINTY
3 DAY	1.53E-06	8.15E-08	2.91E-07	1.98E-07
7 DAY	1.73E-06	9.13E-08	9.10E-08	2.08E-07
7 DAY DU	NA	NA	NA	NA
14 DAY	1.54E-06	8.79E-08	2.85E-07	2.05E-07
14 DAY D	NA	NA	NA	NA

DAY	g SOLUTE/ml	g SOLUTE/g SAND	KD RATIO (ml/g)
3 DAY	3.83E-08	2.71E-08	0.76
7 DAY	4.33E-08	9.10E-09	0.21
7 DAY DU	NA	NA	NA
14 DAY	3.85E-08	2.85E-08	0.74
14 DAY D	NA	NA	NA

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

I 129

HEAD SAMPLE	g IN SOLN.	UNCERTAINTY
10K HD	1.82E-06	1.17E-07
125K HD	2.65E-05	5.04E-07
250K HD	4.31E-05	5.58E-07

10K			g ON SAND	UNCERTAINTY
3 DAY	1.53E-06	8.15E-08	2.91E-07	1.98E-07
3 DAY DUP	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7 DAY	1.73E-06	9.13E-08	9.10E-08	2.08E-07
7 DAY DUP	0.00E+00	0.00E+00	0.00E+00	0.00E+00
14 DAY	1.54E-06	8.79E-08	2.85E-07	2.05E-07

DAY	g OF SAND
3 DAY	10.0015
7 DAY	10.0015
14 DAY	10.002

DAY	g SOLUTE/g SAND
3 DAY	2.91E-08
3 DAY DU	0
7 DAY	9.1E-09
7 DAY DU	0
14 DAY	2.85E-08

DAY	g SOLUTE/ml	g IN SOL	UNCERTAINTY	KD RATIO (ml/g)
3 DAY	3.83E-08	1.53E-06	8.15E-08	0.759182
3 DAY DU	0	0.00E+00	0.00E+00	#DIV/0!
7 DAY	4.33E-08	1.73E-06	9.13E-08	0.210009
7 DAY DU	0	0.00E+00	0.00E+00	#DIV/0!
14 DAY	3.85E-08	1.54E-06	8.79E-08	0.740593

CALCULATED BY________ DATE 5/23/95
CHECKED BY________ DATE 6-6-95
APPROVED BY________ DATE 6-6-95

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

DISTRIBUTION RATIOS

RADIONUCLIDE____ I 129
PROPOSED ACTIVIT 125000 pCi/l
ACTUAL ACTIVITY__ 117149 pCi/l
(AFTER CONTACT EQUILIBRIUM)

ANALYSIS PERIOD_ 4/24/95 - 5/8/95
ANALYST PRESTON
CALCULATED BY________ DATE 5/23/95
CHECKED BY________ DATE 5-24-95
APPROVED BY________ DATE 6-6-98

I 129		
HEAD SAMPLE	g IN SOL	UNCERTAINTY
125K	2.65E-05	5.04E-07

DAY	g OF SAND
3 DAY	10.0016
7 DAY	10.0014
14 DAY	10.0016

DAY	g IN SOL	UNCERTAINTY	g ON SAND	UNCERTAINTY
3 DAY	2.07E-05	3.04E-07	5.81E-06	8.08E-07
7 DAY	1.85E-05	2.82E-07	8.01E-06	7.86E-07
7 DAY DU	NA	NA	NA	NA
14 DAY	2.01E-05	3.29E-07	6.49E-06	8.33E-07
14 DAY D	NA	NA	NA	NA

DAY	g SOLUTE/ml	g SOLUTE/g SAND	KD RATIO (ml/g)
3 DAY	5.18E-07	5.81E-07	1.12
7 DAY	4.63E-07	8.01E-07	1.72
7 DAY DU	NA	NA	NA
14 DAY	5.01E-07	6.49E-07	1.29
14 DAY D	NA	NA	NA

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I 129

HEAD SAMPLE	g IN SOLN.	UNCERTAINTY
10K HD	1.82E-06	1.17E-07
125K HD	2.65E-05	5.04E-07
250K HD	4.31E-05	5.58E-07

125K			g ON SAND	UNCERTAINTY
3 DAY	2.07E-05	3.04E-07	5.81E-06	8.08E-07
3 DAY DUP	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7 DAY	1.85E-05	2.82E-07	8.01E-06	7.86E-07
7 DAY DUP	0.00E+00	0.00E+00	0.00E+00	0.00E+00
14 DAY	2.01E-05	3.29E-07	6.49E-06	8.33E-07

DAY	g OF SAND
3 DAY	10.0016
7 DAY	10.0014
14 DAY	10.0016

DAY	g SOLUTE/g SAND
3 DAY	5.81E-07
3 DAY DU	0
7 DAY	8.01E-07
7 DAY DU	0
14 DAY	6.49E-07

DAY	g SOLUTE/ml	g IN SOL	UNCERTAINTY	KD RATIO (ml/g)
3 DAY	5.18E-07	2.07E-05	3.04E-07	1.120901
3 DAY DU	0	0.00E+00	0.00E+00	#DIV/0!
7 DAY	4.63E-07	1.85E-05	2.82E-07	1.728846
7 DAY DU	0	0.00E+00	0.00E+00	#DIV/0!
14 DAY	5.01E-07	2.01E-05	3.29E-07	1.294556

CALCULATED BY________ DATE 5/23/95
CHECKED BY________ DATE 6-6-95
APPROVED BY________ DATE 6-6-95

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

DISTRIBUTION RATIOS

RADIONUCLIDE____ I 129
PROPOSED ACTIVIT 250000 pCi/l
ACTUAL ACTIVITY__ 190440 pCi/l
(AFTER CONTACT EQUILIBRIUM)

ANALYSIS PERIOD_ 4/24/95 - 5/8/95
ANALYST PRESTON
CALCULATED BY________ DATE 5/23/95
CHECKED BY________ DATE 5/24/95
APPROVED BY________ DATE 6-6-95

I 129

HEAD SAMPLE	g IN SOL	UNCERTAINTY
250K	4.31E-05	5.58E-07

DAY	g OF SAND
3 DAY	10.0025
7 DAY	10.0023
14 DAY	10.0012

DAY	g IN SOL	UNCERTAINTY	g ON SAND	UNCERTAINTY
3 DAY	4.21E-05	8.77E-07	1.05E-06	1.43E-06
7 DAY	4.15E-05	8.87E-07	1.65E-06	1.44E-06
7 DAY DU	5.14E-05	1.04E-06	-8.25E-06	1.59E-06
14 DAY	3.77E-05	8.79E-07	5.45E-06	1.44E-06
14 DAY D	NA	NA	NA	NA

DAY	g SOLUTE/ml	g SOLUTE/g SAND	KD RATIO (ml/g)
3 DAY	1.05E-06	1.05E-07	0.1
7 DAY	1.04E-06	1.65E-07	0.16
7 DAY DU	1.28E-06	-8.20E-07	-0.64
14 DAY	9.42E-07	5.45E-07	0.58
14 DAY D	NA	NA	NA

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

I 129

HEAD SAMPLE	g IN SOLN.	UNCERTAINTY		
10K HD	1.82E-06	1.17E-07		
125K HD	2.65E-05	5.04E-07		
250K HD	4.31E-05	5.58E-07		
250K			g ON SAND	UNCERTAINTY
3 DAY	4.21E-05	8.77E-07	1.05E-06	1.43E-06
3 DAY DUP	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7 DAY	4.15E-05	8.87E-07	1.65E-06	1.44E-06
7 DAY DUP	5.14E-05	1.04E-06	-8.25E-06	1.59E-06
14 DAY	3.77E-05	8.79E-07	5.45E-06	1.44E-06

DAY	g OF SAND
3 DAY	10.0025
7 DAY	10.0023
14 DAY	10.0012

DAY	g SOLUTE/g SAND
3 DAY	1.05E-07
3 DAY DU	0
7 DAY	1.65E-07
7 DAY DU	-8.2E-07
14 DAY	5.45E-07

DAY	g SOLUTE/ml	g IN SOL	UNCERTAINTY	KD RATIO (ml/g)
3 DAY	1.05E-06	4.21E-05	8.77E-07	0.099785
3 DAY DU	0	0.00E+00	0.00E+00	#DIV/0!
7 DAY	1.04E-06	4.15E-05	8.87E-07	0.159076
7 DAY DU	1.28E-06	5.14E-05	1.04E-06	-0.64213
14 DAY	9.42E-07	3.77E-05	8.79E-07	0.578487

CALCULATED BY________ DATE 5/23/95
CHECKED BY________ DATE 6-6-95
APPROVED BY________ DATE 6-6-95

DISTRIBUTION RATIOS

IODINE 129

	pCI/l	pCI/l
SAMPLE	ACTIVITY	ERROR
10K HD	8052	516
3 DAY	6770	360
7 DAY	7652	403
7 DAY X	NA	NA
14 DAY	6794	388
14 DAY X	NA	NA
125K HD	117149	2226
3 DAY	91497	1342
7 DAY	81797	1244
14 DAY	88521	1451
250K HD	190440	2462
3 DAY	185770	3870
7 DAY	183130	3914
7 DAY X	226849	4580
14 DAY	166379	3880

TEST OBSERVATIONS

CONTACT SOLUTION EQUILIBRIUM:

ALL SOLUTIONS EXIBITED A VISIBLE WHITE PRECIPITATE WHICH WAS FILTERED OFF.

3,7 AND 14 DAY SAMPLES:

ALL TEST SOLUTIONS WERE CLEAR AND UNCOLORED.

COUNTING METHOD:

GAS PORPORTIONAL COUNTING

CONCLUSIONS

ALL OF THE TEST SOLUTIONS FOR EACH OF THE THREE DIFFERENT ACTIVITIES EXHIBITED POSITIVE (KD) VALUES WITH THE EXCEPTION OF THE 250K 7 DAY DUP. WITHOUT ANALYZING THE SOIL PORTION OF THIS SAMPLE IT IS DIFFICULT TO DETERMINE IF THIS IS AN ANOMOLY OR NOT.

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

DISTRIBUTION RATIOS

RADIONUCLIDE____ TC 99
PROPOSED ACTIVIT 20000 pCi/l
ACTUAL ACTIVITY__ 39628 pCi/l
(AFTER CONTACT EQUILIBRIUM)

ANALYSIS PERIOD_ 4/24/95 - 5/8/95
ANALYST PRESTON
CALCULATED BY________ DATE 5/22/95
CHECKED BY________ DATE 6-6-95
APPROVED BY________ DATE 6-6-95

TC 99		
HEAD SAMPLE	g IN SOL	UNCERTAINTY
20K HD	9.35E-08	5.31E-09

DAY	g OF SAND
3 DAY	10.0015
7 DAY	10.002
14 DAY	10.0011

DAY	g IN SOL	UNCERTAINTY	g ON SAND	UNCERTAINTY
3 DAY	8.33E-08	2.06E-09	1.02E-08	7.37E-09
7 DAY	7.86E-08	2.01E-09	1.49E-08	7.31E-09
7 DAY DU	8.93E-08	2.18E-09	4.13E-09	7.49E-09
14 DAY	1.09E-07	2.24E-09	-1.53E-08	7.55E-09
14 DAY D	1.14E-07	2.30E-09	-2.08E-08	7.61E-09

DAY	g SOLUTE/ml	g SOLUTE/g SAND	KD RATIO (ml/g)
3 DAY	2.08E-09	1.02E-09	0.49
7 DAY	1.97E-09	1.49E-09	0.76
7 DAY DU	2.23E-09	4.13E-10	0.18
14 DAY	2.72E-09	-1.50E-09	-0.56
14 DAY D	2.86E-09	-2.08E-09	-0.73

TC 99

HEAD SAMPLE	g IN SOLN.	UNCERTAINTY	g ON SAND	UNCERTAINTY
20K HD	9.35E-08	5.31E-09		
300K HD	6.17E-07	1.30E-09		
600K HD	1.23E-06	2.10E-08		
20K				
3 DAY	8.33E-08	2.06E-09	1.02E-08	7.37E-09
7 DAY	7.86E-08	2.01E-09	1.49E-08	7.31E-09
7 DAY DU	8.93E-08	2.18E-09	4.13E-09	7.49E-09
14 DAY	1.09E-07	2.24E-09	-1.53E-08	7.55E-09
14 DAY DU	1.14E-07	2.30E-09	-2.08E-08	7.61E-09

DAY	g OF SAND
3 DAY	10.0015
7 DAY	10.002
14 DAY	10.0011

DAY	g SOLUTE/g SAND
3 DAY	1.02E-09
7 DAY	1.49E-09
7 DAY DU	4.13E-10
14 DAY	-1.5E-09
14 DAY D	-2.1E-09

DAY	g SOLUTE/ml	g IN SOL	UNCERTAINTY	KD RATIO (ml/g)
3 DAY	2.08E-09	8.33E-08	2.06E-09	0.490497
7 DAY	1.97E-09	7.86E-08	2.01E-09	0.756121
7 DAY DU	2.23E-09	8.93E-08	2.18E-09	0.184895
14 DAY	2.72E-09	1.09E-07	2.24E-09	-0.56386
14 DAY D	2.86E-09	1.14E-07	2.30E-09	-0.72923

CALCULATED BY______ DATE 5/23/95
CHECKED BY______ DATE 6-6-95
APPROVED BY______ DATE 6-6-95

DISTRIBUTION RATIOS

RADIONUCLIDE____ TC 99
PROPOSED ACTIVIT 300000 pCi/l
ACTUAL ACTIVITY__ 261462 pCi/l
(AFTER CONTACT EQUILIBRIUM)

ANALYSIS PERIOD_ 4/24/95 - 5/8/95
ANALYST PRESTON
CALCULATED BY__________ DATE 5/23/95
CHECKED BY__________ DATE 6-6-95
APPROVED BY BT DATE 6-6-95

TC 99		
HEAD SAMPLE	g IN SOL	UNCERTAINTY
300K	6.17E-07	1.30E-09

DAY	g OF SAND
3 DAY	10.0023
7 DAY	10.0032
14 DAY	10.0044

DAY	g IN SOL	UNCERTAINTY	g ON SAND	UNCERTAINTY
3 DAY	6.47E-07	1.21E-08	-3.00E-08	1.34E-08
7 DAY	5.88E-07	1.17E-08	2.84E-08	1.30E-08
7 DAY DU	NA	NA	NA	NA
14 DAY	7.59E-07	1.39E-08	-1.43E-07	1.30E-09
14 DAY D	NA	NA	NA	NA

DAY	g SOLUTE/ml	g SOLUTE/g SAND	KD RATIO (ml/g)
3 DAY	1.62E-08	-3.00E-09	-0.19
7 DAY	1.47E-08	2.84E-09	0.19
7 DAY DU	NA	NA	NA
14 DAY	1.90E-08	-1.40E-08	-0.75
14 DAY D	NA	NA	NA

BARRINGER LABORATORIES INC.
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TC 99

HEAD SAMPLE	g IN SOLN.	UNCERTAINTY
20K HD	9.35E-08	5.31E-09
300K HD	6.17E-07	1.30E-09
600K HD	1.23E-06	2.10E-08

300K			g ON SAND	UNCERTAINTY
3 DAY	6.47E-07	1.21E-08	-3.00E-08	1.34E-08
3 DAY DUP	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7 DAY	5.88E-07	1.17E-08	2.84E-08	1.30E-08
7 DAY DUP	0.00E+00	0.00E+00	0.00E+00	0.00E+00
14 DAY	7.59E-07	1.39E-08	-1.43E-07	1.30E-09

DAY	g OF SAND
3 DAY	10.0023
7 DAY	10.0032
14 DAY	10.0044

DAY	g SOLUTE/g SAND
3 DAY	-3E-09
3 DAY DU	0
7 DAY	2.84E-09
7 DAY DU	0
14 DAY	-1.4E-08

DAY	g SOLUTE/ml	g IN SOL	UNCERTAINTY	KD RATIO (ml/g)
3 DAY	1.62E-08	6.47E-07	1.02E-08	-0.18554
3 DAY DU	0	0.00E+00	0.00E+00	#DIV/0!
7 DAY	1.47E-08	5..882E-7	1.17E-08	0.193004
7 DAY DU	0	0.00E+00	0.00E+00	#DIV/0!
14 DAY	1.9E-08	7.59E-07	1.14E-07	-0.75099

CALCULATED BY________ DATE 5/23/95
CHECKED BY BC DATE 6-6-95
APPROVED BY BC DATE 6-6-95

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

DISTRIBUTION RATIOS

RADIONUCLIDE_____ TC 99
PROPOSED ACTIVIT 600000 pCi/l
ACTUAL ACTIVITY__ 522151 pCi/l
(AFTER CONTACT EQUILIBRIUM)

ANALYSIS PERIOD_ 4/24/95 - 5/8/95
ANALYST PRESTON
CALCULATED BY__________ DATE 5/23/95
CHECKED BY__________ DATE 6-6-95
APPROVED BY__________ DATE 6-6-95

TC 99

HEAD SAMPLE	g IN SOL	UNCERTAINTY
600K	1.23E-06	2.10E-08

DAY	g OF SAND
3 DAY	10.0013
7 DAY	10.0013
14 DAY	10.0025

DAY	g IN SOL	UNCERTAINTY	g ON SAND	UNCERTAINTY
3 DAY	1.21E-06	2.33E-08	2.00E-08	4.43E-08
7 DAY	1.31E-06	2.43E-06	-7.50E-08	4.53E-08
7 DAY DU	1.65E-06	3.15E-08	-4.18E-07	5.25E-08
14 DAY	1.59E-06	3.06E-08	-3.61E-07	5.16E-08
14 DAY D	NA	NA	NA	NA

DAY	g SOLUTE/ml	g SOLUTE/g SAND	KD RATIO (ml/g)
3 DAY	3.03E-08	2.00E-09	0.07
7 DAY	3.27E-08	-7.50E-09	-0.23
7 DAY DU	4.12E-08	-4.20E-08	-1.01
14 DAY	3.98E-08	-3.60E-08	-0.91
14 DAY D	NA	NA	NA

BARRINGER LABORATORIES INC.
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TC 99

HEAD SAMPLE	g IN SOLN.	UNCERTAINTY
20K HD	9.35E-08	5.31E-09
300K HD	6.17E-07	1.30E-09
600K HD	1.23E-06	2.10E-08

600K			g ON SAND	UNCERTAINTY
3 DAY	1.21E-06	2.33E-08	2.00E-08	4.43E-08
3 DAY DUP	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7 DAY	1.31E-06	2.43E-06	-7.50E-08	4.53E-08
7 DAY DUP	1.65E-06	3.15E-08	-4.18E-07	5.25E-08
14 DAY	1.59E-06	3.06E-08	-3.61E-07	5.16E-08

DAY	g OF SAND
3 DAY	10.0013
7 DAY	10.0013
14 DAY	10.0025

DAY	g SOLUTE/g SAND
3 DAY	2E-09
3 DAY DU	0
7 DAY	-7.5E-09
7 DAY DU	-4.2E-08
14 DAY	-3.6E-08

DAY	g SOLUTE/ml	g IN SOL	UNCERTAINTY	KD RATIO (ml/g)
3 DAY	3.03E-08	1.21E-06	1.02E-08	0.066053
3 DAY DU	0	0.00E+00	0.00E+00	#DIV/0!
7 DAY	3.27E-08	1.31E-06	1.17E-08	-0.22968
7 DAY DU	4.12E-08	1.65E-06	0.00E+00	-1.01382
14 DAY	3.98E-08	1.59E-06	1.14E-07	-0.90681

CALCULATED BY________ DATE 5/23/95
CHECKED BY________ DATE 6-6-95
APPROVED BY________ DATE 6-6-95

BARRINGER LABORATORIES INC.
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DISTRIBUTION RATIOS

TECHNICIUM 99

	pCi/l	pCi/l
SAMPLE	ACTIVITY	ERROR
20K HD	39627	2261
3 DAY	35307	883
7 DAY	33333	855
7 DAY X	37881	930
14 DAY	46121	952
14 DAY X	48469	969
300K HD	261462	5537
3 DAY	274143	5118
7 DAY	249404	4964
14 DAY	321896	5870
600K HD	522150	8909
3 DAY	513353	9867
7 DAY	553861	10292
14 DAY	699042	13366
14 DAY X	674830	12969

TEST OBSERVATIONS

CONTACT SOLUTION EQUILIBRIUM:

ALL SOLUTIONS EXIBITED A VISIBLE WHITE PRECIPITATE WHICH WAS FILTERED OFF.

3,7,AND 14 DAY SAMPLES:

ALL TEST SOLUTIONS WERE CLEAR AND UNCOLORED.

COUNTING METHOD:

GAS PORPORTIONAL AND LIQUID SCINTILLATION.

CONCLUSIONS:

INITIALLY ALL OF THE TEST SOLUTIONS WERE ANALYZED BY GAS PORPORTIONAL COUNTING PRECEEDED BY A ION EXCHANGE PURIFICATION PROCEDURE.
WHEN USING ANY ANALYTICAL WET CHEMICAL METHOD FOR THE DETERMINATION OF A RADIONUCLIDE A CHEMICAL LOSS WILL OCCUR, HENCE THE SAMPLES WERE RECOUNTED USING LIQUID SCINTILLATION COUNTING WEREUPON THERE IS NO CHEMICAL LOSS. THE RESULTS FROM THE LATTER METHOD WERE USED FOR CALCULATIONS. THE FOLLOWING SAMPLES RESULTED IN (KD) VALUES WHICH WERE NEGATIVE:20K 14 DAY, 300K 3 DAY AND 14 DAY, 600K 7 DAY AND 14 DAY.
THE NEGATIVE VALUES RESULT FROM THE FACT THAT THE GRAMS OF TECHNICIUM IN THE TEST SOLUTIONS WERE HIGHER THAN THE HEAD RESULT. SINCE THE TEST SOLUTIONS WERE ANALYZED ON A VOLUME BASIS THIS WOULD TEND TO SUPPORT THAT SOME HYDRATION OF THE SOIL OCCURRED. IT IS NOT POSSIBLE TO MAKE A DEFINITE CONCLUSION OF THIS THEORY UNLESS THE SOIL FROM EACH OF THE ABOVE QUESTIONABLE NEGATIVE (KD) VALUE SAMPLES ARE ANALYZED PRODUCING A MASS BALANCE.

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

DISTRIBUTION RATIOS

RADIONUCLIDE____ NP 237
PROPOSED ACTIVIT 5000 pCi/l
ACTUAL ACTIVITY__ 364 pCi/l
(AFTER CONTACT EQUILIBRIUM)

ANALYSIS PERIOD_ 4/24/95 - 5/8/95
ANALYST _PRESTON
CALCULATED BY__________ DATE 5/23/95
CHECKED BY__________ DATE 6-6-95
APPROVED BY__________ DATE 6-6-95

NP 237

HEAD SAMPLE	g IN SOL	UNCERTAINTY
5K	2.07E-08	2.03E-08

DAY	g OF SAND
3 DAY	10.0014
7 DAY	10.0019
14 DAY	10.0007

DAY	g IN SOL	UNCERTAINTY	g ON SAND	UNCERTAINTY
3 DAY	0.00E+00	3.42E-10	2.07E-08	2.07E-08
7 DAY	0.00E+00	3.04E-10	2.07E-08	2.06E-08
7 DAY DU	NA	NA	NA	NA
14 DAY	0.00E+00	2.77E-10	2.07E-08	2.06E-08
14 DAY D	NA	NA	NA	NA

DAY	g SOLUTE/ml	g SOLUTE/g SAND	KD RATIO (ml/g)
3 DAY	0.00E+00	2.06E-09	ERR
7 DAY	0.00E+00	2.06E-09	ERR
7 DAY DU	NA	NA	NA
14 DAY	0.00E+00	2.06E-09	ERR
14 DAY D	NA	NA	NA

NP 237

HEAD SAMPLE	g IN SOLN.	UNCERTAINTY
5K HD	2.07E-09	2.03E-09
75K HD	1.23E-07	3.69E-08
150K HD	1.77E-07	4.40E-08

5K			g ON SAND	UNCERTAINTY
3 DAY	0.00E+00	3.09E-10	2.07E-09	2.34E-09
3 DAY DUP	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7 DAY	0.00E+00	3.06E-10	2.07E-09	2.34E-09
7 DAY DUP	0.00E+00	0.00E+00	0.00E+00	0.00E+00
14 DAY	0.00E+00	2.78E-10	2.07E-09	2.31E-09

DAY	g OF SAND
3 DAY	10.0014
7 DAY	10.0019
14 DAY	10.0007

DAY	g SOLUTE/g SAND
3 DAY	2.06E-10
3 DAY DU	0
7 DAY	2.06E-10
7 DAY DU	0
14 DAY	2.06E-10

DAY	g OF SOLUTE/ml	g IN SOL	UNCERTAINTY	KD RATIO (ml/g)
3 DAY	0	0.00E+00	3.09E-10	#DIV/0!
3 DAY DU	0	0.00E+00	0.00E+00	#DIV/0!
7 DAY	0	0.00E+00	3.06E-10	#DIV/0!
7 DAY DU	0	0.00E+00	0.00E+00	#DIV/0!
14 DAY	0	0.00E+00	2.78E-10	#DIV/0!

CALCULATED BY__________ DATE 5/23/95
CHECKED BY__________ DATE 5-23-95
APPROVED BY__________ DATE 6-6-95

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

DISTRIBUTION RATIOS

RADIONUCLIDE____ NP 237
PROPOSED ACTIVIT 75000 pCi/l
ACTUAL ACTIVITY__ 2192 pCi/l
(AFTER CONTACT EQUILIBRIUM)

ANALYSIS PERIOD_ 4/24/95 - 5/8/95
ANALYST PRESTON
CALCULATED BY__________ DATE 5/23/95
CHECKED BY__________ DATE 6-6-95
APPROVED BY__________ DATE 6-6-95

NP 237

HEAD SAMPLE	g IN SOL	UNCERTAINTY
75K	1.23E-07	3.69E-08

DAY	g OF SAND
3 DAY	10.0014
7 DAY	10.0011
14 DAY	10.0013

DAY	g IN SOL	UNCERTAINTY	g ON SAND	UNCERTAINTY
3 DAY	1.25E-09	1.93E-09	1.22E-07	3.88E-08
7 DAY	9.08E-10	2.10E-10	1.22E-07	3.71E-08
7 DAY DU	NA	NA	NA	NA
14 DAY	7.94E-10	2.55E-09	1.23E-07	3.94E-08
14 DAY D	NA	NA	NA	NA

DAY	g SOLUTE/ml	g SOLUTE/g SAND	KD RATIO (ml/g)
3 DAY	3.12E-11	1.22E-08	391.46
7 DAY	2.27E-11	1.22E-08	539.67
7 DAY DU	NA	NA	NA
14 DAY	1.99E-11	1.23E-08	617.35
14 DAY D	NA	NA	NA

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

NP 237		
HEAD SAMPLE	g IN SOLN.	UNCERTAINTY
5K HD	2.07E-09	2.03E-09
75K HD	1.23E-07	3.69E-08
150K HD	1.77E-07	4.40E-08

75K			g ON SAND	UNCERTAINTY
3 DAY	1.25E-09	1.93E-09	1.22E-07	3.88E-08
3 DAY DUP	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7 DAY	9.08E-10	2.10E-10	1.22E-07	3.71E-08
7 DAY DUP	0.00E+00	0.00E+00	0.00E+00	0.00E+00
14 DAY	7.94E-10	2.55E-09	1.23E-07	3.94E-08

DAY	g OF SAND
3 DAY	10.0014
7 DAY	10.0011
14 DAY	10.0013

DAY	g SOLUTE/g SAND
3 DAY	1.22E-08
3 DAY DU	0
7 DAY	1.22E-08
7 DAY DU	0
14 DAY	1.23E-08

DAY	g OF SOLUTE/ml	g IN SOL	UNCERTAINTY	KD RATIO (ml/g)
3 DAY	3.12E-11	1.25E-09	1.93E-09	391.458
3 DAY DU	0	0.00E+00	0.00E+00	#DIV/0!
7 DAY	2.27E-11	9.08E-10	2.10E-10	539.6727
7 DAY DU	0	0.00E+00	0.00E+00	#DIV/0!
14 DAY	1.99E-11	7.94E-10	2.55E-09	617.3474

CALCULATED BY________ DATE 5/23/95
CHECKED BY________ DATE 6-6-95
APPROVED BY________ DATE 6-6-95

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

DISTRIBUTION RATIOS

RADIONUCLIDE____ NP 237
PROPOSED ACTIVIT 150000 pCi/l
ACTUAL ACTIVITY__ 3135 pCi/l
(AFTER CONTACT EQUILIBRIUM)

ANALYSIS PERIOD_ 4/24/95 - 5/8/95
ANALYST PRESTON
CALCULATED BY_______ DATE 5/23/95
CHECKED BY_______ DATE 6-6-95
APPROVED BY_______ DATE 6-6-95

NP 237		
HEAD SAMPLE	g IN SOL	UNCERTAINTY
150K	1.77E-07	4.40E-08

DAY	g OF SAND
3 DAY	10.0022
7 DAY	10.0034
14 DAY	10.003

DAY	g IN SOL	UNCERTAINTY	g ON SAND	UNCERTAINTY
3 DAY	4.71E-09	3.46E-09	1.73E-07	4.74E-08
7 DAY	1.59E-09	2.04E-09	1.76E-07	4.60E-08
7 DAY DU	0.00E+00	1.93E-09	1.77E-07	4.59E-08
14 DAY	1.87E-09	2.33E-09	1.75E-07	4.63E-08
14 DAY D	1.25E-09	2.16E-09	1.76E-07	4.61E-08

DAY	g SOLUTE/ml	g SOLUTE/g SAND	KD RATIO (ml/g)
3 DAY	1.18E-10	1.73E-08	146.57
7 DAY	3.97E-11	1.76E-08	442.17
7 DAY DU	0.00E+00	1.77E-08	ERR
14 DAY	4.68E-11	1.75E-08	374.73
14 DAY D	3.12E-11	1.76E-08	564.1

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

NP 237

HEAD SAMPLE	g IN SOLN.	UNCERTAINTY
5K HD	2.07E-09	2.03E-09
75K HD	1.23E-07	3.69E-08
150K HD	1.77E-07	4.40E-08

150K			g ON SAND	UNCERTAINTY
3 DAY	4.71E-09	3.46E-09	1.73E-07	4.74E-08
3 DAY DUP	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7 DAY	1.59E-09	2.04E-09	1.76E-07	4.60E-08
7 DAY DUP	0.00E+00	1.93E-09	1.77E-07	4.59E-08
14 DAY	1.87E-09	2.33E-09	1.75E-07	4.63E-08
14 DAY DUP	1.25E-09	2.16E-09	1.76E-07	4.61E-08

DAY	g OF SAND
3 DAY	10.0022
7 DAY	10.0034
14 DAY	10.003

DAY	g SOLUTE/g SAND		
3 DAY	1.73E-08		
3 DAY DU	0		
7 DAY	1.76E-08		
7 DAY DU	1.77E-08		
14 DAY	1.75E-08	14 DAY DUP	1.76E-08

DAY	g OF SOLUTE/ml	g IN SOL	UNCERTAINTY	KD RATIO (ml/g)
3 DAY	1.18E-10	4.71E-09	3.46E-09	146.573
3 DAY DU	0	0.00E+00	0.00E+00	#DIV/0!
7 DAY	3.97E-11	1.59E-09	2.04E-09	442.1681
7 DAY DU	0	0.00E+00	1.93E-09	#DIV/0!
14 DAY	4.68E-11	1.87E-09	2.33E-09	374.7337
14 DAY D	3.12E-11	1.25E-09	2.16E-09	564.1

CALCULATED BY ________ DATE 5/23/95
CHECKED BY ________ DATE 6-6-95
APPROVED BY ________ DATE 6-6-95

DISTRIBUTION RATIOS

NEPTUNIUM 237

	pCi/l	pCi/l
SAMPLE	ACTIVITY	ERROR
5K HD	364	358
3 DAY	0	6
7 DAY	0	5.4
7 DAY X	NA	NA
14 DAY	0	4.9
14 DAY X	NA	NA
75K HD	2192	648
3 DAY	22	34
7 DAY	16	37
14 DAY	14	45
150K HD	3135	778
3 DAY	83	61
7 DAY	28	36
7 DAY X	0	34
14 DAY	33	41
14 DAY X	22	38

TEST OBSERVATIONS

CONTACT SOLUTION EQUILIBRIUM:

THERE WAS NO VISIBLE PRECIPITATE PRESENT PRIOR TO FILTERING.

3,7 AND 14 DAY SAMPLES:

ALL TEST SOLUTIONS WERE CLEAR AND UNCOLORED.

COUNTING METHOD:

ALPHA SPECTROSCOPY.

CONCLUSIONS

ALL OF THE TEST SOLUTION RESULTS ARE EXTREMELY LOW RESULTING IN A BAD NEPTUNIUM STANDARD PURCHASED FROM ISOTOPE PRODUCTS. UPON THIS OBSERVATION THE REMAINING PORTION OF THE STANDARD WAS ANALYZED BY 3 INDEPENDENT METHODS TO DETERMINE THE ACTUAL ACTIVITY. THE 3 METHODS USED WERE AS FOLLOWS: DIRECT MOUNT, LANTHANUM FLUORIDE PRECIPITATION AND BY A GAMMA SPEC SCAN. ALL THREE OF THESE METHODS CONCLUDED THAT THE ACTUAL ACTIVITY OF THE STANDARD PURCHASED FROM ISOTOPE PRODUCTS WAS ONLY 3% OF THE STATED ACTIVITY. THE QA/QC MANAGER HAS BEEN CONTACTED AND IS GOING TO SHIP ANOTHER NEPTUNIUM STANDARD TO BARRINGER LABORATORIES THE WEEK OF JUNE 5, 1995.

FROM THE ABOVE TABLE LISTING THE TEST SAMPLE ACTIVITIES IT CAN BE SEEN THAT THE COUNTING ERROR ASSOCIATED WITH EACH OF THE SAMPLES ARE VERY LARGE MAKING IT VERY DIFFICULT TO CALCULATE ANY REASONABLE (KD) VALUES.

DISTRIBUTION RATIOS

RADIONUCLIDE C 14
PROPOSED ACTIVIT 10000 pCi/l
ACTUAL ACTIVITY 10304 pCi/l
(AFTER CONTACT EQUILIBRIUM)

ANALYSIS PERIOD 4/21/95 - 5/5/95
ANALYST PRESTON
CALCULATED BY DATE 5/23/95
CHECKED BY DATE 6-5-95
APPROVED BY DATE 6-6-95

C 14		
HEAD SAMPLE	g IN SOL	UNCERTAINTY
10K	9.24E-11	2.69E-12

DAY	g OF SAND
3 DAY	10.0009
7 DAY	10.0013
14 DAY	10.0023

DAY	g IN SOL	UNCERTAINTY	g ON SAND	UNCERTAINTY
3 DAY	2.04E-11	2.47E-12	7.20E-11	5.16E-12
7 DAY	2.56E-11	2.69E-12	6.68E-11	5.38E-12
7 DAY DU	NA	NA	NA	NA
14 DAY	2.58E-11	2.69E-12	6.66E-11	5.38E-12
14 DAY D	NA	NA	NA	NA

DAY	g SOLUTE/ml	g SOLUTE/g SAND	KD RATIO (ml/g)
3 DAY	5.10E-13	7.20E-12	14.11
7 DAY	6.39E-13	6.68E-12	10.46
7 DAY DU	NA	NA	NA
14 DAY	6.45E-13	6.66E-12	10.33
14 DAY D	NA	NA	NA

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

C 14

HEAD SAMPLE	g IN SOLN.	UNCERTAINTY		
10K HD	9.24E-11	2.69E-12		
250K HD	2.29E-09	1.21E-11		
500K HD	4.38E-09	1.68E-11		
10K			g ON SAND	UNCERTAINTY
3 DAY	2.04E-11	2.47E-12	7.20E-11	5.16E-12
3 DAY DUP	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7 DAY	2.56E-11	2.69E-12	6.68E-11	5.38E-12
7 DAY DUP	0.00E+00	0.00E+00	0.00E+00	0.00E+00
14 DAY	2.58E-11	2.69E-12	6.66E-11	5.38E-12

DAY	g OF SAND
3 DAY	10.0009
7 DAY	10.0013
14 DAY	10.0023

DAY	g SOLUTE/g SAND
3 DAY	7.2E-12
3 DAY DU	0
7 DAY	6.68E-12
7 DAY DU	0
14 DAY	6.66E-12

DAY	g SOLUTE/ml	g IN SOL	UNCERTAINTY	KD RATIO (ml/g)
3 DAY	5.1E-13	2.04E-11	2.47E-12	14.11246
3 DAY DU	0	0.00E+00	0.00E+00	#DIV/0!
7 DAY	6.39E-13	2.56E-11	2.69E-12	10.4556
7 DAY DU	0	0.00E+00	0.00E+00	#DIV/0!
14 DAY	6.45E-13	2.58E-11	2.69E-12	10.32566

CALCULATED BY ______ DATE 5/23/95
CHECKED BY ______ DATE 6-6-95
APPROVED BY ______ DATE 6.6.95

DISTRIBUTION RATIOS

RADIONUCLIDE____ C 14
PROPOSED ACTIVIT 250000 pCi/l
ACTUAL ACTIVITY__ 254910 pCi/l
(AFTER CONTACT EQUILIBRIUM)

ANALYSIS PERIOD_ 4/21/95 - 5/5/95
ANALYST PRESTON
CALCULATED BY________ DATE 5/23/95
CHECKED BY__________ DATE 6-6-95
APPROVED BY_________ DATE 6-6-95

C 14		
HEAD SAMPLE	g IN SOL	UNCERTAINTY
250K	2.29E-09	1.21E-11

DAY	g OF SAND
3 DAY	10.0027
7 DAY	10.0019
14 DAY	10.0024

DAY	g IN SOL	UNCERTAINTY	g ON SAND	UNCERTAINTY
3 DAY	5.39E-10	5.83E-12	1.75E-09	1.79E-11
7 DAY	7.59E-10	6.95E-12	1.53E-09	1.91E-11
7 DAY DU	NA	NA	NA	NA
14 DAY	7.64E-10	6.95E-12	1.52E-09	1.91E-11
14 DAY D	NA	NA	NA	NA

DAY	g SOLUTE/ml	g SOLUTE/g SAND	KD RATIO (ml/g)
3 DAY	1.35E-11	1.75E-10	12.95
7 DAY	1.90E-11	1.53E-10	8.05
7 DAY DU	NA	NA	NA
14 DAY	1.91E-11	1.52E-10	7.97
14 DAY D	NA	NA	NA

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

C 14

HEAD SAMPLE	g IN SOLN.	UNCERTAINTY
10K HD	9.24E-11	2.69E-12
250K HD	2.29E-09	1.21E-11
500K HD	4.38E-09	1.68E-11

250K			g ON SAND	UNCERTAINTY
3 DAY	5.39E-10	5.83E-12	1.75E-09	1.79E-11
3 DAY DUP	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7 DAY	7.59E-10	6.95E-12	1.53E-09	1.91E-11
7 DAY DUP	0.00E+00	0.00E+00	0.00E+00	0.00E+00
14 DAY	7.64E-10	6.95E-12	1.52E-09	1.91E-11

DAY	g OF SAND
3 DAY	10.0027
7 DAY	10.0019
14 DAY	10.0024

DAY	g SOLUTE/g SAND
3 DAY	1.75E-10
3 DAY DU	0
7 DAY	1.53E-10
7 DAY DU	0
14 DAY	1.52E-10

DAY	g SOLUTE/ml	g IN SOL	UNCERTAINTY	KD RATIO (ml/g)
3 DAY	1.35E-11	5.39E-10	2.47E-12	12.95496
3 DAY DU	0	0.00E+00	0.00E+00	#DIV/0!
7 DAY	1.9E-11	7.59E-10	2.69E-12	8.045902
7 DAY DU	0	0.00E+00	0.00E+00	#DIV/0!
14 DAY	1.91E-11	7.64E-10	2.69E-12	7.968241

CALCULATED BY________ DATE 5/23/95
CHECKED BY________ DATE 6-~~16~~6-95
APPROVED BY________ DATE 6-6-95

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

DISTRIBUTION RATIOS

RADIONUCLIDE____ C 14
PROPOSED ACTIVIT 500000pCi/l
ACTUAL ACTIVITY__ 488672 pCi/l
(AFTER CONTACT EQUILIBRIUM)

ANALYSIS PERIOD_ 4/21/95 - 5/5/95
ANALYST _PRESTON
CALCULATED BY__________ DATE 5/23/95
CHECKED BY__________ DATE 6-6-95
APPROVED BY__________ DATE 6-6-95

C 14

HEAD SAMPLE	g IN SOL	UNCERTAINTY
500K	4.38E-09	1.68E-11

DAY	g OF SAND
3 DAY	10.0023
7 DAY	10.0009
14 DAY	10.0015

DAY	g IN SOL	UNCERTAINTY	g ON SAND	UNCERTAINTY
3 DAY	1.34E-09	9.19E-12	3.04E-09	2.60E-11
7 DAY	1.41E-09	9.42E-09	2.98E-09	9.43E-09
7 DAY DU	NA	NA	NA	NA
14 DAY	1.48E-09	2.91E-09	2.91E-09	1.49E-09
14 DAY D	NA	NA	NA	NA

DAY	g SOLUTE/ml	g SOLUTE/g SAND	KD RATIO (ml/g)
3 DAY	3.36E-11	3.04E-10	9.06
7 DAY	3.52E-11	2.98E-10	8.46
7 DAY DU	NA	NA	NA
14 DAY	3.70E-11	2.90E-10	7.86
14 DAY D	NA	NA	NA

C 14

HEAD SAMPLE	g IN SOLN.	UNCERTAINTY
10K HD	9.24E-11	2.69E-12
250K HD	2.29E-09	1.21E-11
500K HD	4.38E-09	1.68E-11

500K			g ON SAND	UNCERTAINTY
3 DAY	1.34E-09	9.19E-12	3.04E-09	2.60E-11
3 DAY DUP	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7 DAY	1.41E-09	9.42E-09	2.98E-09	9.43E-09
7 DAY DUP	0.00E+00	0.00E+00	0.00E+00	0.00E+00
14 DAY	1.48E-09	1.48E-09	2.91E-09	1.49E-09

DAY	g OF SAND
3 DAY	10.0023
7 DAY	10.0009
14 DAY	10.0015

DAY	g SOLUTE/g SAND
3 DAY	3.04E-10
3 DAY DU	0
7 DAY	2.98E-10
7 DAY DU	0
14 DAY	2.9E-10

DAY	g SOLUTE/ml	g IN SOL	UNCERTAINTY	KD RATIO (ml/g)
3 DAY	3.36E-11	1.34E-09	9.19E-12	9.061999
3 DAY DU	0	0.00E+00	0.00E+00	#DIV/0!
7 DAY	3.52E-11	1.41E-09	9.42E-12	8.459793
7 DAY DU	0	0.00E+00	0.00E+00	#DIV/0!
14 DAY	3.7E-11	1.48E-09	9.64E-12	7.860797

CALCULATED BY ________ DATE 5/23/95
CHECKED BY ________ DATE 6-6-95
APPROVED BY ________ DATE 6-6-95

BARRINGER LABORATORIES INC
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

DISTRIBUTION RATIOS

CARBON 14

	pCi/l	pCi/l
SAMPLE	ACTIVITY	ERROR
10K HD	10304	297
3 DAY	2274	279
7 DAY	2842	292
7 DAY X	NA	NA
14 DAY	2866	292
14 DAY X	NA	NA
250K HD	254910	1350
3 DAY	60126	662
7 DAY	84636	782
14 DAY	85170	784
500K HD	488672	1869
3 DAY	149639	1036
7 DAY	156833	1058
14 DAY	1664750	1086

TEST OBSERVATIONS

CONTACT SOLUTION EQUILIBRIUM:

ALL SOLUTIONS EXIBITED A VISIBLE WHITE PRECIPITATE WHICH WAS FILTERED OFF.

3,7 AND 14 DAY SAMPLES:

ALL TEST SOLUTIONS WERE CLEAR AND UNCOLORED.

COUNTING METHOD:

GAS PORPORTIONAL AND LIQUID SCINTILLATION.

CONCLUSIONS

INITIALLY ALL TEST SOLUTIONS WERE ANALYZED BY GAS PORPORTIONAL COUNTING PRECEEDED BY PURIFICATION USING ION EXCHANGE RESIN WHEN USING ANY WET CHEMICAL METHOD FOR THE DETERMINATION OF A RADIONUCLIDE A CHEMICAL LOSS WILL OCCUR, HENCE THE SAMPLES WERE RECOUNTED USING LIQUID SCINTILLATION COUNTING WHEREUPON THERE IS NO CHEMICAL LOSS. THE RESULTS FROM THE THE RESULTS FROM THE LATTER METHOD WERE USED FOR CALCULA TIONS.
ALL TEST SOLUTIONS AT EACH OF THE 3 DIFFERENT ACTIVITIES EXIBITED POSTIVE BUT DECREASING (KD) VALUES AS A FUNCTION OF TIME.

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

DISTRIBUTION RATIOS

RADIONUCLIDE____ U-NAT
PROPOSED ACTIVIT 40000 pCi/l
ACTUAL ACTIVITY__ 43938 pCi/l

(AFTER CONTACT EQUILIBRIUM)

ANALYSIS PERIOD_ 5/16-6/1/95
ANALYST _PRESTON
CALCULATED BY________ DATE 6/5/95
CHECKED BY________ DATE 6-5-95
APPROVED BY________ DATE 6-6-95

U-NAT

HEAD SAMPLE	g IN SOL	UNCERTAINTY
40K	2.60E-03	0.00E+00

DAY	g OF SAND
3 DAY	10.0007
7 DAY	10.0036
16 DAY	10.0011

DAY	g IN SOL	UNCERTAINTY	g ON SAND	UNCERTAINTY
3 DAY	1.16E-05	0.00E+00	2.59E-03	0.00E+00
3 DAY DU	1.19E-05	0.00E+00	2.59E-03	0.00E+00
7 DAY	1.02E-03	0.00E+00	1.58E-03	0.00E+00
7 DAY DU	9.88E-04	0.00E+00	1.61E-03	0.00E+00
16 DAY	1.06E-03	0.00E+00	1.54E-03	0.00E+00

DAY	g SOLUTE/ml	g SOLUTE/g SAND	KD RATIO (ml/g)
3 DAY	2.9E-07	0.000259	892.49
3 DAY DU	2.98E-07	0.000259	869.89
7 DAY	2.55E-05	0.000158	6.19
7 DAY DU	2.47E-05	1.61E-04	6.52
16 DAY	2.65E-05	1.54E-04	5.81

U-NAT

HEAD SAMPLE	g IN SOLN.	UNCERTAINTY		
40K HD	2.60E-03	0.00E+00		
40K			g ON SAND	UNCERTAINTY
3 DAY	1.16E-05	0.00E+00	2.59E-03	0.00E+00
3 DAY DUP	1.19E-05	0.00E+00	2.59E-03	0.00E+00
7 DAY	1.02E-03	0.00E+00	1.58E-03	0.00E+00
7 DAY DUP	9.88E-04	0.00E+00	1.61E-03	0.00E+00
14 DAY	1.06E-03	0.00E+00	1.54E-03	0.00E+00

DAY	g OF SAND
3 DAY	10.0007
7 DAY	10.0036
14 DAY	10.0011

DAY	g SOLUTE/g SAND
3 DAY	0.000259
3 DAY DU	0.000259
7 DAY	0.000158
7 DAY DU	0.000161
14 DAY	0.000154

DAY	g SOLUTE/ml	g IN SOL	UNCERTAINTY	KD RATIO (ml/g)
3 DAY	2.9E-07	1.16E-05	0.00E+00	892.4892
3 DAY DU	2.98E-07	1.19E-05	0.00E+00	869.8887
7 DAY	2.55E-05	1.02E-03	0.00E+00	6.193849
7 DAY DU	2.47E-05	9.88E-04	0.00E+00	6.523967
14 DAY	2.65E-05	1.06E-03	0.00E+00	5.810682

*NOTE: THERE IS NO ERROR REPORTED WITH FLUOROMETRIC URANIUM RESULTS.

CALCULATED BY________ DATE 6/5/95
CHECKED BY________ DATE 6-5-95
APPROVED BY________ DATE 6

BARRINGER LABORATORIES INC.
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DISTRIBUTION RATIOS

URANIUM NAT

	pCi/l	pCi/l
SAMPLE	ACTIVITY	ERROR
40K HD	43938	0
3 DAY	196	0
3 DAY X	202	0
7 DAY	17331	0
7 DAY X	16722	0
16 DAY	17873	0

TEST OBSERVATIONS

CONTACT SOLUTION EQUILIBRIUM:
THERE WAS NO VISIBLE PRECIPITATE AFTER EQUILIBRIUM.

3,7 AND 16 DAY SAMPLES:

ALL TEST SOLUTIONS WERE CLEAR AND UNCOLORED.

COUNTING METHOD:

FLUOROMETRIC AND KPA

CONCLUSIONS

THE U-NAT STANDARD WHICH WAS PURCHASED HAD TO BE CONCENTRATED DOWN TO APPROXIMATELY 10 MLS SUCH THAT THE ALIQUOTS TAKEN FOR THE CONTACT SOLUTIONS WOULD BE EQUIVALENT TO THE OTHER 4 RADIONUCLIDES. UPON CONCENTRATION THE URANIUM STANDARD PRECIPITATED OUT OF SOLUTION. THE ONLY WAY TO KEEP THE URANIUM IN SOLUTION WAS TO ADD NITRIC ACID. UPON ADDITION OF THIS STANDARD TO THE 20,000,000 AND 40,000,000 pCi/l SAMPLES A YELLOW PRECIPITATE FORMED WHICH COULD NOT BE REDISSOLVED. THIS PRECIPITATION DID NOT OCCUR WITH THE 40,000 pCi/l SAMPLES HOWEVER THE RESULTING pH WAS 1.5. THE pH WAS ADJUSTED TO pH 7.7 AND THE TEST WAS CONTINUED. FROM THE ABOVE TABLE IT WOULD APPEAR THAT AT THE 3 DAY SAMPLE ESSENTIALLY ALL OF THE URANIUM ABSORBED ONTO THE SOIL BUT STARTED TO COME OFF AT THE 7 AND 16 DAY SAMPLES. ALL OF THE (KD) VALUES WERE POSITIVE. BECAUSE THE 3 DAY SAMPLE WAS VERY LOW COMPARED TO THE 7 AND 16 DAY SAMPLES IT WAS REANALYZED BY KPA THE KPA RESULTS VERIFIED THE FLUOROMETRIC RESULS. TO DETERMINE IF THE 3 DAY SAMPLE IS AN ANOMOLY THE SOIL PORTION OF THIS SAMPLE SHOULD BE ANALYZED FOR A MASS BALANCE.

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

BINGHAM DISTRIBUTION RATIOS

=low activity
=medium activity
=[illegible]h activity

1=3 day
2=7 day
3=[illegible] day

Nuclide	Solution	Soil Comp. weight (g)	Contact Soln. density	Contact Date	Contact Time	End Date	End Time	pH	Eh	Shake Time(days)
C14	L1	10.0009	1.0101	04/21	19:45	04/24	20:45	7.32	151.0	3.042
	L2	10.0013		04/21	19:50	04/28	18:00	7.34	224.3	6.924
	L3	10.0023		04/21	19:55	05/05	18:30	7.57	227.1	13.941
	M1	10.0027	1.0258	04/21	20:00	04/24	20:45	7.32	151.0	3.031
	M2	10.0019		04/21	20:05	04/28	18:00	7.34	224.3	6.913
	M3	10.0024		04/21	20:10	05/05	18:30	7.57	227.1	13.931
	H1	10.0023	1.0372	04/21	20:15	04/24	20:45	7.32	151.0	3.021
	H2	10.0009		04/21	20:20	04/28	18:00	7.34	224.3	6.903
	H3	10.0015		04/21	20:25	05/05	18:30	7.57	227.1	13.920
I 129	L1	10.0015	1.0286	04/24	12:45	04/27	17:30	7.28	204.8	3.198
	L2	10.0015		04/24	13:05	05/01	19:45	7.51	221.4	7.278
	L3	10.002		04/24	13:10	05/08	15:30	7.58	204.1	14.097
	M1	10.0016	1.0319	04/24	13:15	04/27	17:30	7.28	204.8	3.177
	M2	10.0014		04/24	13:25	05/01	19:45	7.51	221.4	7.264
	M3	10.0016		04/24	13:30	05/08	15:30	7.58	204.1	14.083
	H1	10.0025	1.0325	04/24	13:35	04/27	17:30	7.28	204.8	3.163
	H2	10.0023		04/24	13:45	05/01	19:45	7.51	221.4	7.250
	H3	10.0012		04/24	13:55	05/08	15:30	7.58	204.1	14.066
Np 237	L1	10.0014	1.0362	04/24	14:20	04/27	17:30	7.22	200.9	3.132
	L2	10.0019		04/24	14:25	05/01	19:45	7.34	221.5	7.222
	L3	10.0007		04/24	14:35	05/08	15:30	7.55	200.5	14.038
	M1	10.0014	1.0379	04/24	14:50	04/27	17:30	7.22	200.9	3.111
	M2	10.0011		04/24	14:55	05/01	19:45	7.34	221.5	7.201
	M3	10.0013		04/24	15:00	05/08	15:30	7.55	200.5	14.021
	H1	10.0022	1.0393	04/24	15:10	04/27	17:30	7.22	200.9	3.097
	H2	10.0034		04/24	15:15	05/01	19:45	7.34	221.5	7.188
	H3	10.003		04/24	15:30	05/08	15:30	7.55	200.5	14.000
Tc 99	L1	10.0015	1.0378	04/24	15:35	04/27	17:30	7.35	205.6	3.080
	L2	10.002		04/24	15:40	05/01	19:45	7.55	225.9	7.170
	L3	10.0011		04/24	15:45	05/08	15:30	7.59	199.7	13.990
	M1	10.0023	1.0342	04/24	16:45	04/27	17:30	7.35	205.6	3.031
	M2	10.0032		04/24	16:50	05/01	19:45	7.55	225.9	7.122
	M3	10.0044		04/24	16:55	05/08	15:30	7.59	199.7	13.941
	H1	10.0013	1.0361	04/24	17:05	04/27	17:30	7.35	205.6	3.017
	H2	10.0013		04/24	17:10	05/01	19:45	7.55	225.9	7.108
	H3	10.0025		04/24	17:15	05/08	15:30	7.59	199.7	13.927
U-nat.	L1	10.0007	1.029	05/16	18:30	05/19	18:00	8.05	206.8	2.979
	L2	10.0036		05/16	18:35	05/23	19:00	7.84	201.6	7.017
	L3	10.0011		05/16	18:40	06/01	19:00	7.78	179.6	16.014

Nuclide	Solution	Soil/ Soln.		Contact Soln.	
		pH	Eh	Eh	Conductance
C 14	L	7.73	255	215.5	56.3
	M				
	H				
I 129	L	7.82	237.2	204.6	56.6
	M				
	H				
Np 237	L	7.81	231.1	205.8	57.6
	M				
	H				
Tc 99	L	7.83	230.8	218.2	57.8
	M				
	H				
U-nat.	L1	7.61	204.1		57.1
	L2				
	L3				

mV mV umho/cm
X 100,000

ADDITIONAL DATA

STANDARD	BLI#
TC-99	3496
U-NAT	3502
NP-237	3497
I-129	3494
C-14	3495

SPECIFIC ACTIVITY EQUATION

SPECIFIC ACTIVITY = 1.880254E23/ (T x A) pCi/g

WHERE: T = THE HALF LIFE IN MINUTES
A= THE ATOMIC MASS IN GRAMS

THE SPECIFIC ACTIVITIES USED:

TC-99	1.696E10 pCi/g
U-NAT	6.77E5 pCi/g
NP-237	7.05E8 pCi/g
I-129	1.766E8 pCi/g
C-14	4.46E12 pCi/g

PERCENT MOISTURE OF THE SOIL COMPOSITE

WET WT.(g) = 1507.1
DRY WT.(g) = 1413.2
% MOISTURE = 6.2

951671

TC 99 DISTRIBUTION RATIOS RECOUNTED BY LIQUID SCINTILLATION

ACTIVITY BALANCE(AFTER EQUILIBRIUM)

HEAD	KNOWN (pCI)	FILTRATE(pCI)	FILTER(pCI)	TOTAL	%BALANCE
20K	400	325 +/- 7	6 +/- 1	331	82.8*
300K	6000	5071 +/- 27	46+/- 3	5117	85.3*
600K	12000	9922 +/- 37	87 +/- 4	10009	83.4*

*NOTE: REMAINING ACTIVITY IS PROBABLY STILL IN THE C-TUBE SINCE THE C-TUBE COULD NOT BE WASHED WHEN THE SAMPLE WAS FILTERED.

SAMPLE	ACTIVITY(pCI/l)
20K HEAD	16288 +/- 353
3 DAY	22260 +/- 404
7 DAY	23304 +/- 414
14 DAY	34627 +/- 501
300K HEAD	253558 +/- 1336
3 DAY	245985 +/- 1313
7 DAY	247543 +/- 1325
14 DAY	249346 +/- 1328
600K HEAD	496119 +/- 1862
3 DAY	480307 +/- 1834
7 DAY	485372 +/- 1846
14 DAY	487953 +/- 1861

BARRINGER LABORARORIES INC

DISTRIBUTION RATIOS

RADIONUCLIDE TC99
PROPOSED ACTIVITY 20000 pCi/l
ACTUAL ACTIVITY 16288 pCi/l
(AFTER CONTACT EQUILIBRIUM)

ANALYSIS PERIOD 4/24/95 - 5/8/95
ANALYST PRESTON
CALCULATED BY DATE 6/28/95
CHECKED BY DATE 6-28-95
APPROVED BY DATE 6-28-95

TC99		
HEAD SAMPLE	g IN SOL	UNCERTAINTY
20K	3.84E-08	8.33E-10

DAY	g OF SAND
3 DAY	10.0015
7 DAY	10.002
14 DAY	10.0011

DAY	g IN SOL	UNCERTAINTY	g ON SAND	UNCERTAINTY
3 DAY	5.25E-08	9.53E-10	-1.41E-08	1.79E-09
7 DAY	5.50E-08	9.76E-10	-1.66E-08	1.81E-09
7 DAY DU	NA	NA	NA	NA
14 DAY	8.17E-08	1.18E-09	-4.33E-08	2.01E-09
14 DAY D	NA	NA	NA	NA

DAY	g SOLUTE/ml	g SOLUTE/g SAND	KD RATIO (ml/g)
3 DAY	1.31E-09	-1.4E-09	-1.07
7 DAY	1.38E-09	-1.7E-09	-1.21
7 DAY DU	NA	NA	NA
14 DAY	2.04E-09	-4.33E-09	-2.12
14 DAY D	NA	NA	NA

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

TC 99

HEAD SAMPLE	g IN SOLN.	UNCERTAINTY
20K HD	3.84E-08	8.33E-10
300K HD	5.98E-07	3.15E-09
600K HD	1.17E-06	4.39E-09

20K			g ON SAND	UNCERTAINTY
3 DAY	5.25E-08	9.53E-10	-1.41E-08	1.79E-09
7 DAY	5.50E-08	9.76E-10	-1.66E-08	1.81E-09
7 DAY DU			#VALUE!	#VALUE!
14 DAY	8.17E-08	1.18E-09	-4.33E-08	2.01E-09
14 DAY DU			#VALUE!	#VALUE!

DAY	g OF SAND
3 DAY	10.0015
7 DAY	10.002
14 DAY	10.0011

DAY	g SOLUTE/g SAND
3 DAY	-1.4E-09
7 DAY	-1.7E-09
7 DAY DU	#VALUE!
14 DAY	-4.3E-09
14 DAY D	#VALUE!

DAY	g SOLUTE/ml	g IN SOL	UNCERTAINTY	KD RATIO (ml/g)
3 DAY	1.31E-09	5.25E-08	9.53E-10	-1.07412
7 DAY	1.38E-09	5.50E-08	9.76E-10	-1.20703
7 DAY DU	#VALUE!			#VALUE!
14 DAY	2.04E-09	8.17E-08	1.18E-09	-2.11972
14 DAY D	#VALUE!			#VALUE!

CALCULATED BY________ DATE 6/28/95
CHECKED BY________ DATE 6-28-95
APPROVED BY________ DATE 6-28-95

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

BARRINGER LABORARORIES INC

DISTRIBUTION RATIOS

RADIONUCLIDE TC99
PROPOSED ACTIVITY 300000 pCI/l
ACTUAL ACTIVITY 253558 pCI/l
(AFTER CONTACT EQUILIBRIUM)

ANALYSIS PERIOD 4/24/95 - 5/8/95
ANALYST PRESTON
CALCULATED BY DATE 6/28/95
CHECKED BY DATE 6-28-95
APPROVED BY DATE 6-28-95

TC99

HEAD SAMPLE	g IN SOL	UNCERTAINTY
300K	5.98E-07	3.15E-09

DAY	g OF SAND
3 DAY	10.0023
7 DAY	10.0032
14 DAY	10.0044

DAY	g IN SOL	UNCERTAINTY	g ON SAND	UNCERTAINTY
3 DAY	5.80E-07	3.10E-09	1.80E-08	6.25E-09
7 DAY	5.84E-07	3.13E-09	1.40E-08	6.28E-09
7 DAY DU	NA	NA	NA	NA
14 DAY	5.88E-07	3.13E-09	1.00E-08	6.28E-09
14 DAY D	NA	NA	NA	NA

DAY	g SOLUTE/ml	g SOLUTE/g SAND	KD RATIO (ml/g)
3 DAY	1.45E-08	1.8E-09	0.124
7 DAY	1.46E-08	1.4E-09	0.096
7 DAY DU	NA	NA	NA
14 DAY	1.47E-08	1.00E-09	0.068
14 DAY D	NA	NA	NA

BARRINGER LABORATORIES INC.
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TC 99

HEAD SAMPLE	g IN SOLN.	UNCERTAINTY		
20K HD	3.84E-08	8.33E-10		
300K HD	5.98E-07	3.15E-09		
600K HD	1.17E-06	4.39E-09		
300K			g ON SAND	UNCERTAINTY
3 DAY	5.80E-07	3.10E-09	1.80E-08	6.25E-09
7 DAY	5.84E-07	3.13E-09	1.40E-08	6.28E-09
7 DAY DU			#VALUE!	#VALUE!
14 DAY	5.88E-07	3.13E-09	1.00E-08	6.28E-09
14 DAY DU			#VALUE!	#VALUE!

DAY	g OF SAND
3 DAY	10.0023
7 DAY	10.0032
14 DAY	10.0044

DAY	g SOLUTE/g SAND
3 DAY	1.8E-09
7 DAY	1.4E-09
7 DAY DU	#VALUE!
14 DAY	1E-09
14 DAY D	#VALUE!

DAY	g SOLUTE/ml	g IN SOL	UNCERTAINTY	KD RATIO (ml/g)
3 DAY	1.45E-08	5.80E-07	3.10E-09	0.124109
7 DAY	1.46E-08	5.84E-07	3.13E-09	0.09586
7 DAY DU	#VALUE!			#VALUE!
14 DAY	1.47E-08	5.88E-07	3.13E-09	0.067997
14 DAY D	#VALUE!			#VALUE!

CALCULATED BY__________ DATE 6/28/95
CHECKED BY__________ DATE 6-28-95
APPROVED BY__________ DATE 6-28-95

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

TC 99

HEAD SAMPLE	g IN SOLN.	UNCERTAINTY		
20K HD	3.84E-08	8.33E-10		
300K HD	5.98E-07	3.15E-09		
600K HD	1.17E-06	4.39E-09		
600K			g ON SAND	UNCERTAINTY
3 DAY	1.13E-06	4.32E-09	4.00E-08	8.71E-09
7 DAY	1.14E-06	4.35E-09	3.00E-08	8.74E-09
7 DAY DU			#VALUE!	#VALUE!
14 DAY	1.15E-06	4.38E-09	2.00E-08	8.77E-09
14 DAY DU			#VALUE!	#VALUE!

DAY	g OF SAND
3 DAY	10.0013
7 DAY	10.0013
14 DAY	10.0025

DAY	g SOLUTE/g SAND
3 DAY	4E-09
7 DAY	3E-09
7 DAY DU	#VALUE!
14 DAY	2E-09
14 DAY D	#VALUE!

DAY	g SOLUTE/ml	g IN SOL	UNCERTAINTY	KD RATIO (ml/g)
3 DAY	2.83E-08	1.13E-06	4.32E-09	0.141575
7 DAY	2.85E-08	1.14E-06	4.35E-09	0.105249
7 DAY DU	#VALUE!			#VALUE!
14 DAY	2.88E-08	1.15E-06	4.38E-09	0.069548
14 DAY D	#VALUE!			#VALUE!

CALCULATED BY________ DATE 6/28/95
CHECKED BY________ DATE 6-28-95
APPROVED BY________ DATE 6.28.95

BARRINGER LABORATORIES INC.
15000 W. 6TH AVE., SUITE 300 GOLDEN, CO 80401 (303) 277-1687 FAX (303) 277-1689

BARRINGER LABORARORIES INC

DISTRIBUTION RATIOS

RADIONUCLIDE____ TC99
PROPOSED ACTIVIT Y 600000 pCI/l
ACTUAL ACTIVITY__ 496119 pCI/l
(AFTER CONTACT EQUILIBRIUM)

ANALYSIS PERIOD_ 4/24/95 - 5/8/95
ANALYST _PRESTON
CALCULATED BY________ DATE 6/28/95
CHECKED BY________ DATE 6-28-95
APPROVED BY________ DATE 6-28-95

TC99

HEAD SAMPLE	g IN SOL	UNCERTAINTY
600K	1.17E-06	4.39E-09

DAY	g OF SAND
3 DAY	10.0013
7 DAY	10.0013
14 DAY	10.0025

DAY	g IN SOL	UNCERTAINTY	g ON SAND	UNCERTAINTY
3 DAY	1.13E-06	4.32E-09	4.00E-08	8.71E-09
7 DAY	1.14E-06	4.35E-09	3.00E-08	8.74E-09
7 DAY DU	NA	NA	NA	NA
14 DAY	1.15E-06	4.38E-09	2.00E-08	8.77E-09
14 DAY D	NA	NA	NA	NA

DAY	g SOLUTE/ml	g SOLUTE/g SAND	KD RATIO (ml/g)
3 DAY	2.83E-08	4.00E-09	0.142
7 DAY	2.85E-08	3.00E-09	0.105
7 DAY DU	NA	NA	NA
14 DAY	2.88E-08	2.00E-09	0.07
14 DAY D	NA	NA	NA

APPENDIX E

STATISTICAL EVALUATION

DISTRIBUTION RATIO EVALUATION

2019-013

July 27, 1995

I. Summary of Results From Barringer And Statistical Evaluation

Kd (ml/g) Raw Data Including Dups

	C-14			I-129			Np-237			Tc-99 (second test)			U (natural)		
Test	Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High
3 day	14.11	12.95	9.06	0.76	1.12	0.1		391.46	146.57	-1.07	0.12	0.14	892.490		
3 day dup													869.890		
7 day	10.46	8.05	8.46	0.21	1.72	0.16		539.67	442.17	-1.21	0.10	0.11	6.190		
7 day dup						-0.64							6.520		
14 day	10.33	7.97	7.86	0.74	1.29	0.58		617.35	374.73	-2.12	0.07	0.07	5.810		
14 day dup									564.1						
Test Avg	11.63	9.66	8.46	0.57	1.38	0.05		516.2	381.9	-1.47	0.10	0.11	356.180	ERR	ERR
Test Std	2.15	2.85	0.60	0.31	0.31	0.51		114.8	175.4	0.57	0.03	0.04	479.333	ERR	ERR
		Total Avg	9.92		Total Avg	0.60		Total Avg	439.44		Total Avg	-0.42		Total Avg	356.180
		Total Std	2.15		Total Std	0.65		Total Std	146.14		Total Std	0.79		Total Std	428.728
		Total Max	14.11		Total Max	1.72		Total Max	617.35		Total Max	0.14		Total Max	892.490
		Total Min	7.86		Total Min	-0.64		Total Min	146.57		Total Min	-2.12		Total Min	5.810

Kd (ml/g) Transformed Data (1), (2)

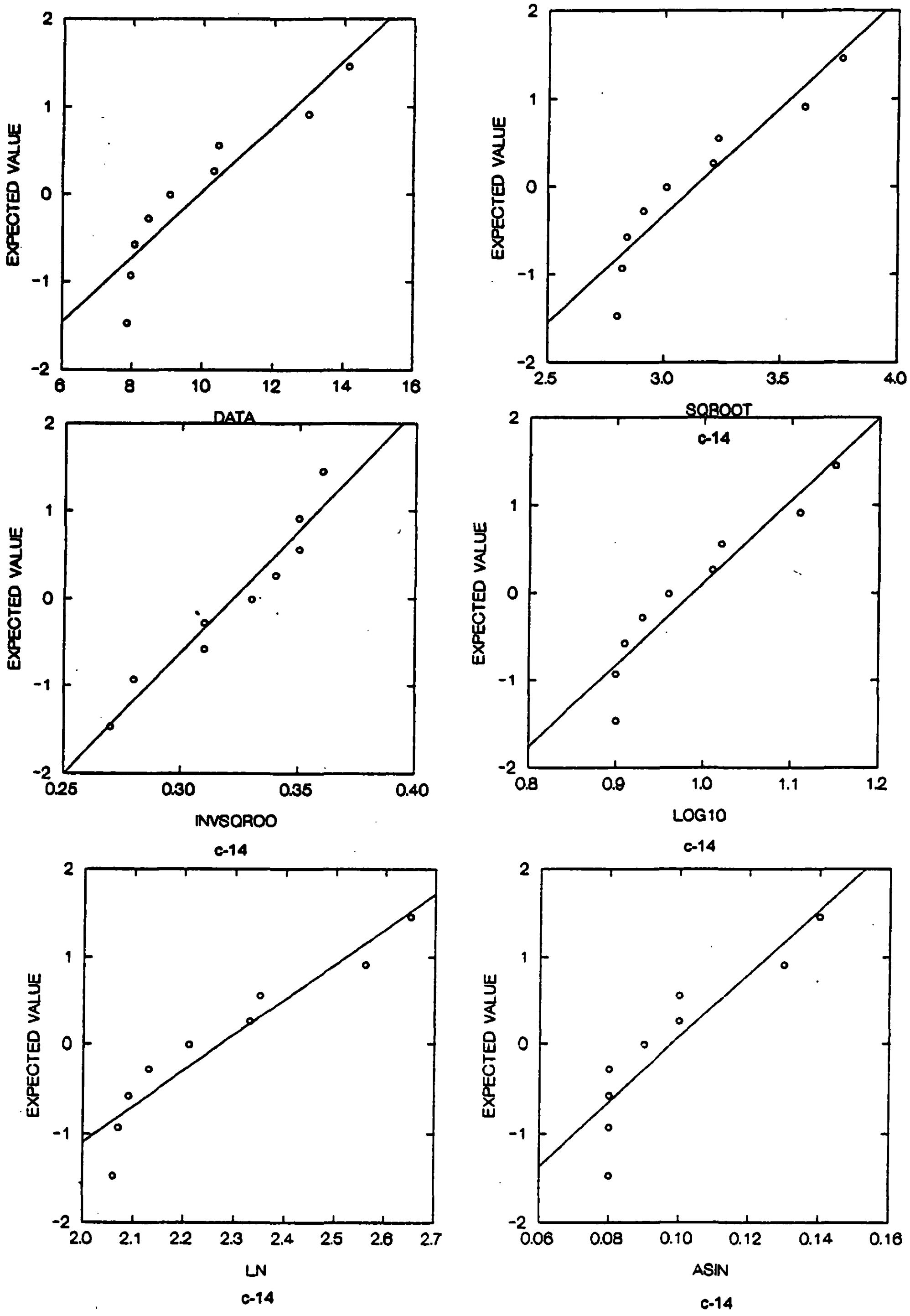
	C-14			I-129			Np-237			Tc-99 (second test)			U (natural)		
Measured	Transform	1/sqr root	Value	Transform	Raw	Value	Transform	Raw	Value	Transform	Raw	Value	Transform	Raw	Value
	Avg	0.32	9.61	Avg	0.74	0.74	Avg	418.50	418.50	Avg	0.07	0.07	Avg	6.00	6.00
	Max	0.27	14.12	Max	1.73	1.73	Max	619.57	619.57	Max	0.14	0.14	Max	6.19	6.19
	Min	0.36	7.86	Min	0.10	0.10	Min	146.89	146.89	Min	0.00	0.00	Min	5.81	5.81
	Range		6.25	Range		1.63	Range		472.68	Range		0.14	Range		0.38
- uncert.	Transform	asin	Value	Transform	Raw	Value	Transform	Raw	Value	Transform	Raw	Value	Transform	Raw	Value
	Avg	0.08	7.54	Avg	0.60	0.60	Avg	86.44	86.44	Avg	0.06	0.06	Avg	not performed	
	Max	0.13	12.81	Max	1.64	1.64	Max	436.02	436.02	Max	0.13	0.13	Max		
	Min	0.00	0.00	Min	0.00	0.00	Min	0.00	0.00	Min	0.00	0.00	Min		
	Range		12.81	Range		1.64	Range		436.02	Range	0.12	0.12	Range		
+ uncert.	Transform	asin	Value	Transform	Raw	Value	Transform	Raw	Value	Transform	Raw	Value	Transform	Raw	Value
	Avg	0.09	8.83	Avg	0.89	0.89	Avg	210.51	210.51	Avg	0.08	0.08	Avg	not performed	
	Max	0.17	16.61	Max	1.82	1.82	Max	700.78	700.78	Max	0.16	0.16	Max		
	Min	0.00	0.00	Min	0.18	0.18	Min	0.00	0.001	Min	0.00	0.00	Min		
	Range		16.61	Range		1.64	Range		700.78	Range	0.16	0.16	Range		

(1) Use 0.001 as Kd value if value is calculated to be negative.

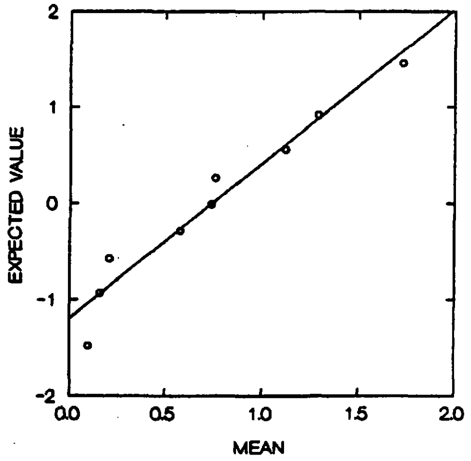
(2) The Kd value calculated for the duplicates was not included in the average

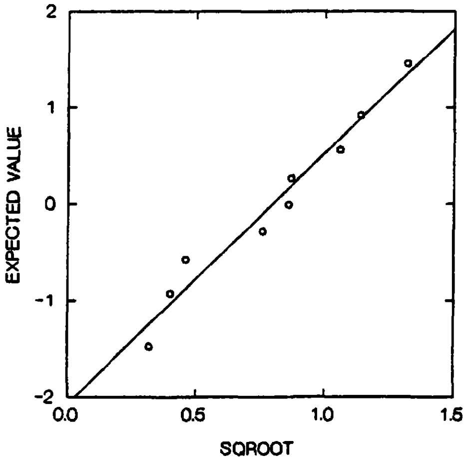
201913.WB2

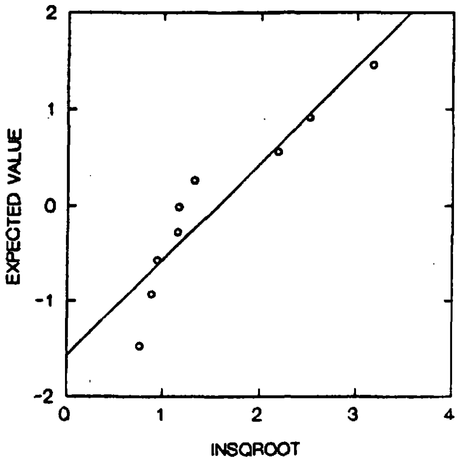
C-14 - Measured Values

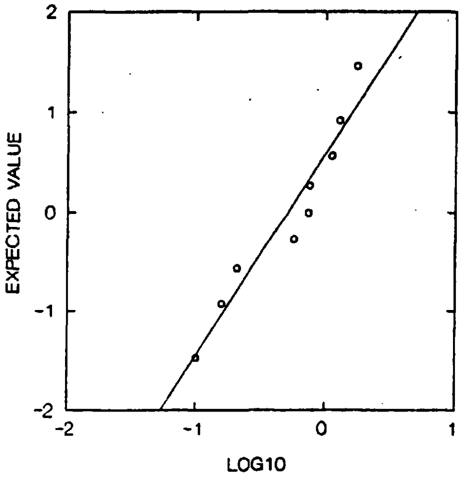


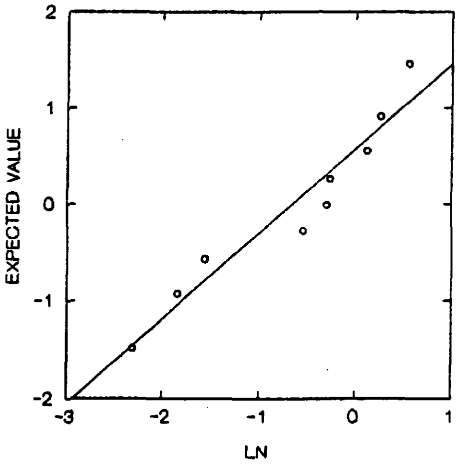
I-129 Data - Mean Values

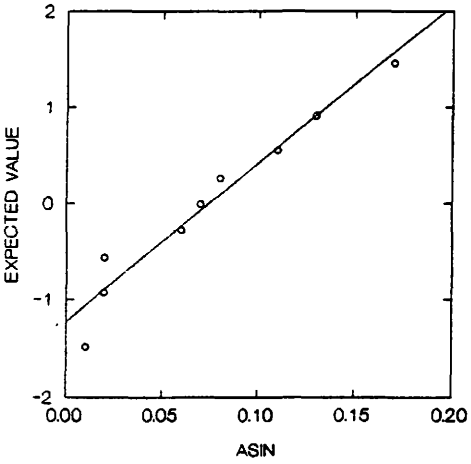




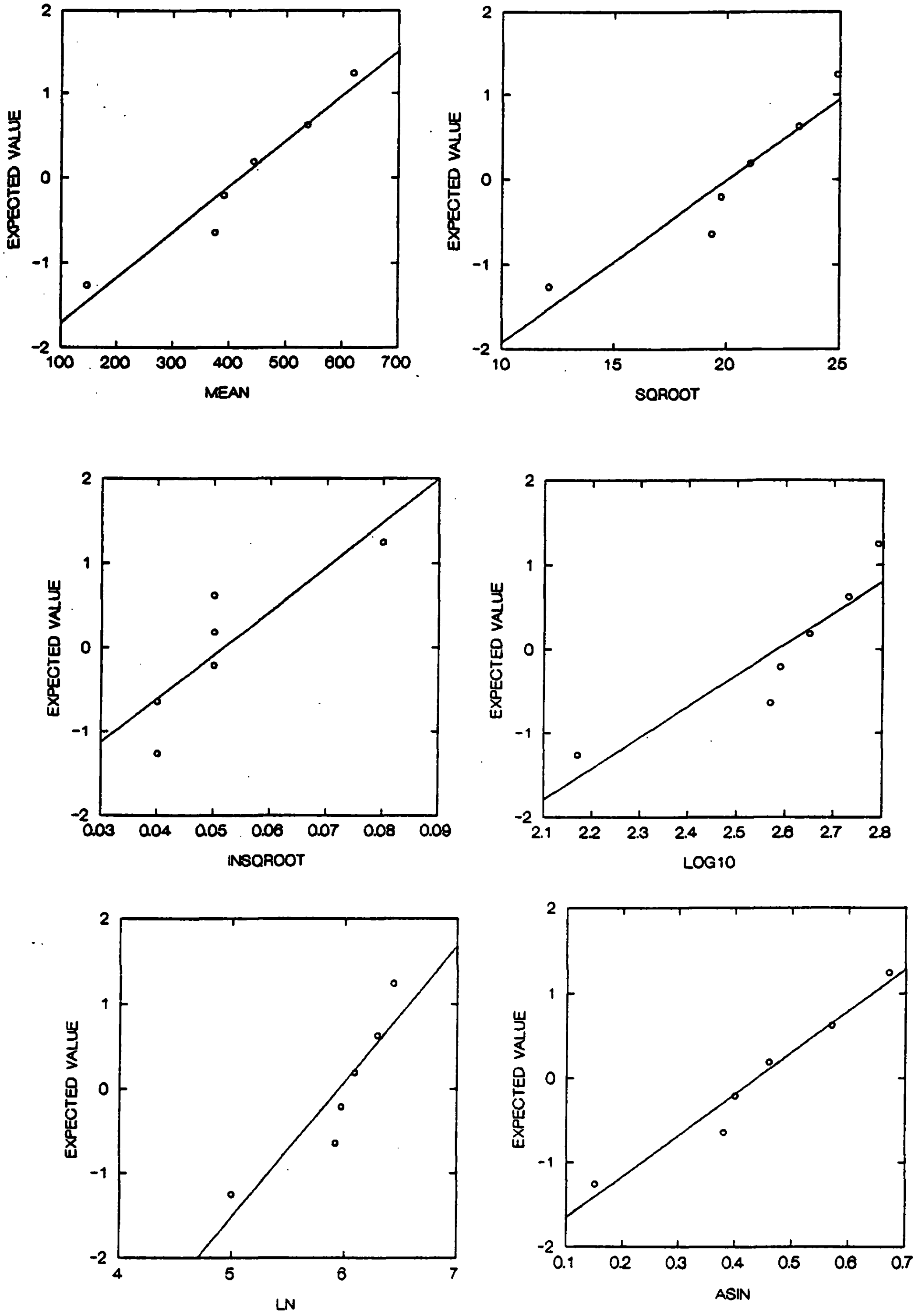


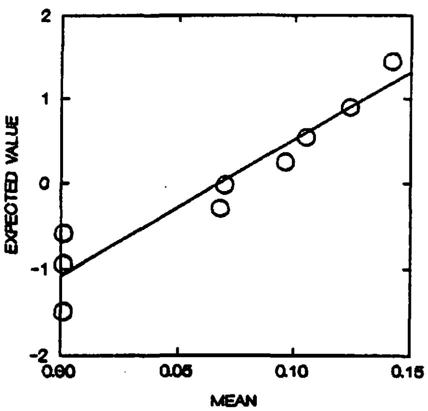


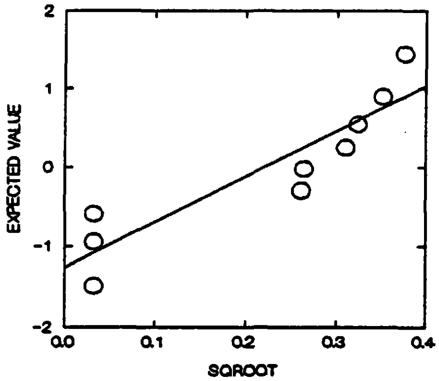




Np-237 Data - Measured Values




Tc-99, (second test)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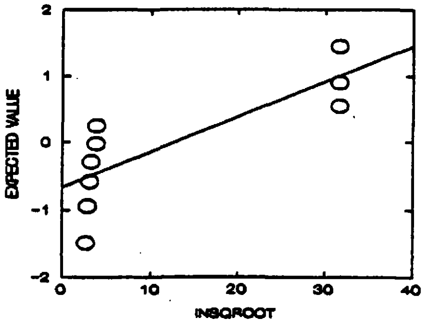
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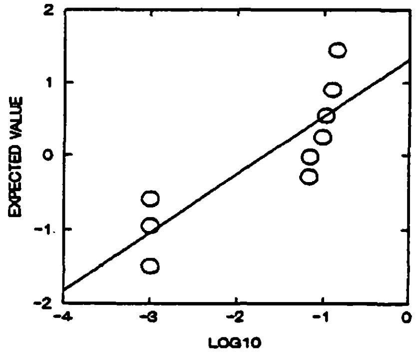
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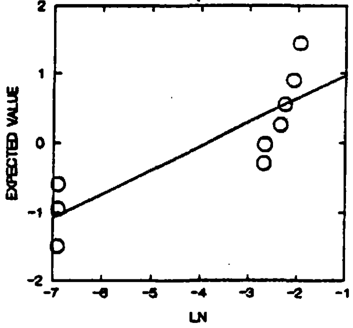
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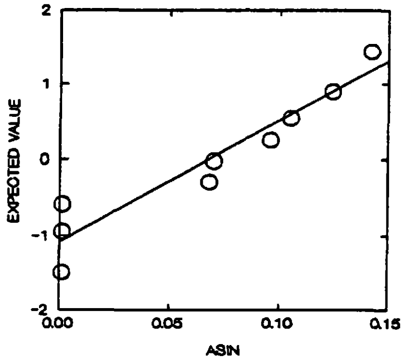
Tc-99 (second test)

Tc-99 - Measured Values

First Test