

**Hazen Research, Inc.**

4601 Indiana Street  
Golden, CO 80403 USA  
Tel: (303) 279-4501  
Fax: (303) 278-1528

October 28, 2002

Mr. Garet E. Van De Steeg  
Cimarron Corporation  
c/o Van De Steeg, Inc.  
2312 N. W. 113<sup>th</sup> Place  
Oklahoma City, OK 73120-7305

Re: Determination of Distribution Coefficients ( $K_d$ ) for Uranium in Soils  
Hazen Project 9936

Dear Mr. Van De Steeg:

On September 20, 2002, Hazen Research, Inc. received two soil samples and one water sample from Cimarron Corporation (Cimarron). All samples were contained in 1-L, high-density polyethylene bottles packed in blue ice. The water was reported to contain about 5,000 pCi/L of uranium. Upon receipt, the samples were assigned Hazen numbers for internal identification and future reference as shown in Table 1. After logging in, samples were stored in a refrigerator at about 4°C. You requested that Hazen determine a distribution ratio ( $R_d$ ) for uranium between each soil and the water following the procedure given in ASTM D 4319-93, Standard Test Method for Distribution Ratios by the Short-Term Batch Method (enclosed). The distribution ratios will be used by Cimarron to determine distribution coefficients ( $K_d$ ) for the soils.

**Table 1. Sample Identification**

HRI	Cimarron Identification
50622-01	02W02-FA1563 Soil (2 Containers)
50622-02	02W08-FA1564 Soil (2 Containers)
50622-03	02W04-1606 Water (8 Containers)

The first soil (02W02-FA1563) appeared to be high in clay content, while the second soil (02W02-FA1564) appeared to be very sandy. Both soil samples had standing water on their surfaces when received. By mutual agreement, the soil samples were dried at about 60°C, resulting in a moisture loss of 25.3% for the clay sample and 15.8% for the sandy sample. The dried cakes were broken up, and test samples of about 25 g each were removed by riffle splitting. An additional sample from each dried soil was further dried at 105°C to obtain residual moisture,

which was 3.0% for the clay soil and 0.5% for the sandy soil. Overall moisture contents of the as-received soils were determined to be 27.5% for the clay soil and 16.2% for the sandy soil. At the request of Mr. Jim Crawford, the sandy soil was also wet screened at 200 mesh (75  $\mu\text{m}$ ) and was found to contain 28.3% minus 200-mesh material.

A head sample of the water was taken on September 25 for uranium analysis. Three head samples were taken on September 26: one corresponding for water used for the clay soil (Head), one for the sandy soil (Head A, 9/26), and one for the blanks (Head B, 9/26). The three samples taken on September 26 were analyzed for uranium, pH, specific conductivity, and Eh. Results are shown in Table 2. The uranium values were used in the distribution ratio calculations. The  $R_d$  tests were performed in triplicate for each sampling period (3, 6, 9, and 15 days), and a blank (B1, B2, B3, and B4) was included for each period.

**Table 2. Compositions of Head and Blank Samples**

Sample	U mg/L	pH	Sp. Cond. $\mu\text{mho/cm}$	Eh mV
Head, 9/25	3.9	--	--	--
Head, 9/26	4.1	8.40	1,310	550
Head A, 9/26	3.3	8.53	1,290	530
Head B, 9/26	3.5	8.69	1,310	530
<b>Average</b>	<b>3.6</b>	<b>8.54</b>	<b>1,303</b>	<b>537</b>
Blanks				
B1 (3 Days)	3.0	8.53	1,260	490
B2 (6 Days)	3.5	8.69	1,320	470
B3 (9 Days)	3.0	8.63	1,300	430
B4 (15 Days)	2.7	8.61	1,259	410

These results show that very little plating of uranium from solution onto container walls occurred during the course of the 15-day test. The uranium in the blanks, 2.7 to 3.5 mg/L, is only slightly less than the average in the heads, 3.6 mg/L.

About 25 g of soil (weighed to the nearest 0.1 g) for each sample were placed into a 250-mL, flat-bottomed, polypropylene centrifuge tube. Contaminated water was added in the amount of exactly four times the weight of soil, or about 100 mL, and the tube was sealed with a cap. The samples were gently shaken on a shaking table for 3 hr on Day 1 and 3 hr on Day 2 for each sampling period, then allowed to settle until sampling time. At sampling time, the appropriate

samples were centrifuged for about 20 min, which resulted in very clear solutions. The clear solutions were decanted and placed into high-density, polyethylene bottles with screw caps. The solution samples for uranium analysis were acidified to less than 2 pH with nitric acid; the remaining solutions were left as they were for analysis. Solids were not analyzed, but were retained for possible future characterization.

Tables 3 and 4 show the analytical results and the calculated  $R_d$  values for the 02W02-FA1563 (clay) and 02W08-FA1564 (sandy) soils, respectively. The  $R_d$  values were calculated as follows:

1. The uranium concentration in the sampled solution was subtracted from the concentration in the starting solution. As an example and referring to Tables 2 and 3 and the average uranium analyses therein, the starting solution contained 3.6 mg/L, and the first sample contained 2.4 mg/L U, resulting in a difference of 1.2 mg/L U. This value is considered the amount of uranium absorbed by solids and possibly precipitated or plated on the container walls.
2. The uranium content of the blank was subtracted from the starting solution composition, which was considered to be loss due to plating only. Following the example above, the blank from the first sampling period contained 3.0 mg/L U. Subtracting this value from the starting solution content of 3.6 mg/L results in 0.6 mg/L U. The difference between Points 1 and 2 (0.6 mg/L) is considered to be the amount of uranium absorbed by solids.
3. The uranium content absorbed by solids was then converted to a uranium value in mg/kg. For example, 0.6 mg/L times 0.1 L (the amount of contaminated water added to 25 g of solids) is 0.06 mg of U that was absorbed onto 0.025 kg of solids, resulting in a calculated solids analysis of 2.4 mg/kg. A value for  $R_d$  was calculated by dividing the calculated solids content (mg/kg) by the solution content (mg/L), as shown in the following formula:

$$R_d = \frac{(\text{Mass of Solute in the Solid Phase per Unit Mass of Solid Phase})}{(\text{Mass of Solute in Solution per Unit Volume of the Liquid Phase})}$$

or

$$\frac{2.4 \text{ mg/kg (Calculated Uranium in the Solids)}}{2.4 \text{ mg/L (Solution Content)}} = 1.0 \text{ mL/g}$$

4. The next iterated step is calculated by using the solution analysis from the previous sampling period as the starting solution and using the analysis of the blank for that particular sampling period. As an example, for the 6-day period, the average starting

**Table 3. Analytical Results and Distribution Ratios for Sample 02W02-FA1563 (Clay)**

<b>Sample</b>	<b>U mg/L</b>	<b>pH</b>	<b>Sp. Cond. <math>\mu</math>mho/cm</b>	<b>Eh mV</b>	<b>U, <math>R_d</math><sup>1</sup></b>
3-day					
1,1	2.5	8.61	1,400	520	0.7
1,2	2.4	8.67	1,350	480	1.0
1,3	2.3	8.70	1,300	460	1.2
<b>Average</b>	<b>2.4</b>	<b>8.66</b>	<b>1,350</b>	<b>487</b>	<b>1.0</b>
6-day					
1,4	2.6	8.56	1,350	530	1.3
1,5	2.0	8.63	1,340	510	3.2
1,6	1.9	8.60	1,390	490	3.6
<b>Average</b>	<b>2.1</b>	<b>8.60</b>	<b>1,360</b>	<b>510</b>	<b>2.7</b>
9-day					
1,7	1.9	8.63	1,330	420	2.4
1,8	1.9	8.68	1,360	450	2.4
1,9	2.1	8.77	1,390	450	1.6
<b>Average</b>	<b>2.0</b>	<b>8.69</b>	<b>1,360</b>	<b>440</b>	<b>2.2</b>
15-day					
1,10	1.7	8.82	1,365	410	2.5
1,11	1.3	8.91	1,365	440	4.7
1,12	1.9	8.77	1,312	460	1.9
<b>Average</b>	<b>1.6</b>	<b>8.83</b>	<b>1,347</b>	<b>437</b>	<b>3.0</b>

<sup>1</sup>  $R_d$  determined by dividing the calculated solids analysis (mg/kg) by the solution analysis (mg/L).

**Table 4. Analytical Results and Distribution Ratios for Sample 02W08-FA1564 (Sand)**

<b>Sample</b>	<b>U mg/L</b>	<b>pH</b>	<b>Sp. Cond. <math>\mu</math>mho/cm</b>	<b>Eh mV</b>	<b>U, <math>R_d</math><sup>1</sup></b>
3-day					
2,1	2.5	8.67	1,360	470	0.8
2,2	2.3	8.81	1,340	480	1.2
2,3	2.5	8.73	1,370	480	0.8
<b>Average</b>	<b>2.4</b>	<b>8.74</b>	<b>1,357</b>	<b>477</b>	<b>1.0</b>
6-day					
2,4	1.8	8.51	1,370	500	3.8
2,5	2.2	8.61	1,390	520	2.3
2,6	2.3	8.61	1,330	480	2.1
<b>Average</b>	<b>2.1</b>	<b>8.58</b>	<b>1,363</b>	<b>500</b>	<b>2.7</b>
9-day					
2,7	2.0	8.81	1,340	440	2.1
2,8	1.9	8.81	1,340	440	2.4
2,9	1.9	8.81	1,380	430	2.4
<b>Average</b>	<b>1.9</b>	<b>8.81</b>	<b>1,353</b>	<b>437</b>	<b>2.3</b>
15-day					
2,10	1.4	8.98	1,291	440	3.5
2,11	1.4	8.82	1,280	400	4.0
2,12	2.0	8.65	1,312	400	1.6
<b>Average</b>	<b>1.6</b>	<b>8.82</b>	<b>1,294</b>	<b>413</b>	<b>3.0</b>

<sup>1</sup>  $R_d$  determined by dividing the calculated solids analysis (mg/kg) by the solution analysis (mg/L).

Mr. Garet Van De Steeg

October 28, 2002

Page 6

solution analysis, as shown in Table 3, is 2.4 mg/L U, and the blank analysis (B2) is 3.5 mg/L U. The blank analysis appears to be anomalously high, which resulted in an anomalously higher  $R_d$  of 2.7 mL/g.

As shown in Tables 3 and 4, the  $R_d$  values for both the soil samples are similar, with averages ranging from 1.0 to 3.0. The results show that some absorption appears to occur during the first 3-day period, after which the absorption slows or stops. Plating also appears to have slowed or stopped after the first 3-day period.

We hope the data presented here prove beneficial to you. Should you have any questions concerning the test work or results, please call either Rick Kenney or me. We look forward to hearing from you again soon.

Yours very truly,



Dennis M. Johnson  
Consultant

DMJ:wlk

Enclosure

xc: Jerry Downey, Hazen  
Rick Kenney, Hazen