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ADSORPTION STUDY FOR URANIUM IN ROCKY FLATS GROUNDWATER

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ABSTRACT

Six adsorbents were studied to determine their effectiveness in removing uranium in Rocky Flats groundwater. The bench column and batch (Kd) tests showed that uranium can be removed (>99.9%) by four adsorbents - Bone Charcoal, F-1 Alumina, BIOFIX, and SORBPLUS. The batch Kd (ml/g) and effluent pH values are - 2.1 $x10^6$ (9.5-11.6) for SORBPLUS; 2.2 $x10^4$ (6.6-7.5) for BIOFIX; 1.0 $x10^4$ (pH 7.9) for F-1 Alumina; and 6.0 $x10^2$ (pH 7.7) for Bone Charcoal. Due to pH consideration, a combination of SORBPLUS (5-10%) with F-1 Alumina or BIOFIX may be a viable option to achieve the maximum efficiency for uranium removal in Rocky Flats groundwater.

INTRODUCTION

Adsorption study was performed under the Sitewide Treatability Studies Program, to determine the effectiveness of six adsorbent materials in removing uranium from Rocky Flats groundwater. The adsorbents were: Bone Charcoal (R1022); F-1 Alumina (granular activated alumina); BIOFIX (immobilized biological agent); SORBPLUS (mixed metal oxide); Filtrasorb 300 (granular activated carbon); and Zeolite (clinoptilolite). Their properties are shown In Table 1.

Bench scale column experiments were performed to establish the retention factors (influent/effluent) for these adsorbents. Based on the column performance, batch Kd (partition coefficient) values were determined with different adsorbent weight to solution volume ratios (1:50, 1:100, 1:200, 1:400, and 1:1000) to evaluate the adsorbent relative loading capacities and adsorption isotherms. The purpose of this study was to identify the adsorbents and parameters such as pH, that can effectively remove uranium (>99.9%) from contaminated groundwater.

EXPERIMENTAL

The groundwater identified for this study was GW3086 (pH 7.6). It contained uranium concentration of 200 ug/L or 66.7 pCi/L, while the discharge limit or the potential ARAR (Applicable or Relevant and Appropriate Requirements) value for uranium is 5 pCi/L.

Bench scale column experiments involved a cylindrical column 2.5 cm in diameter containing 15 cm of adsorbent. The feed solution was passed through the column via a peristaltic pump with a constant flow rate of 1.5 to 2.0 ml/min. The bed volume was 50-60 cc, which gave a column residence time of 20-40 minutes. About 50 column volumes (2.4 liters) were passed through the column.

The batch experiments consisted of adsorbent weight to solution volume ratios of 1:50, 1:100, 1:200, 1:400, and 1:1000 using 50 ml of feed solution in a plastic bottle. The bottles were mounted on a tumbler and tumbled at 30 rpm for about 24 hours. The solutions were then filtered through a 0.45 um medium. Aliquots were taken to measure the pH, and uranium concentration by a Kinetic Phosphorescence analyzer (ChemCheck, KPA-11).

DISCUSSION

Column: Bench scale column tests showed that uranium levels in the effluents ranged from 0.02 to 180 ug/L, while the influent uranium concentration was 200 ug/L. Thus, the retention factors (RF; influent/effluent) ranged from about 1 to 10,000. The RFs for uranium removal were 625 for Bone Charcoal, 5000 for BIOFIX, 6670 for F-1 Alumina, and 10,000 for SORBPLUS. The RFs were about 1 for Filtrasorb 300 (activated charcoal) and Zeolite (Clinoptilolite), indicating no retention of uranium by these adsorbents.

Table 1. Adsorbent Type

Adsorbent	Type (Comm. Name)	Manufacturer	Size-Mesh	Quantity (g)*
Filtrasorb 300	Granular Activated carbon	Calgon Carbon Corp.	12 x 40	30
F-1 Alumina	Granular Activated Alumina	ALCOA Industrial Chemicals	28 x 48	63
SORBPLUS	Mixed Metal Oxide	ALCOA Industrial Chemicals	20 x 40	61
BIO-FIX	Immobilized Biological Agent	Amoco Performance Products	N/A	40
Bone Charcoal	R1022	Rockland International, Inc.	N/A	53
Natural Zeolite	Clinoptilolite	East-West Minerals, Inc.	20 x 35	68

* Amount used in 2.5 cm x 15 cm column.

Based on the high RFs, SORBPLUS is the most effective adsorbent in removing uranium from the solution. However, SORBPLUS is a metal oxide, and it yielded hydroxide anion in solution; thus the effluent pH was quite high (12.6). This requires a neutralization step prior to discharge, which makes it less attractive.

An effluent with a neutral pH can be discharged into the existing water system. Therefore, adsorbents that yielded a near neutral effluent were preferred. The pH values for the other three adsorbents were between 7.4 and 8.3, close to the influent pH of 7.6.

Batch (Kd): The batch Kd is defined as the ratio of an element's concentration in the solid phase (ug/g) to the liquid phase (ug/ml), and thus is expressed in units of ml/g as shown below.

$$\text{Batch Kd} = \frac{\text{Solid (ug/g)}}{\text{Liquid (ug/ml)}} = \frac{\text{ml (Influent - Effluent)}}{\text{g (Effluent)}}$$

As the retention factor (RF) increases, so does the magnitude of the batch Kd value. Thus, the batch Kd values provide information on the adsorbent relative to its loading capacities and nature of the adsorption isotherms for defining solid versus solution relationships in a flowing system.

The batch Kd values (ml/g) for Bone Charcoal varied from 4.0×10^2 to 7.4×10^2, with a mean value of 6.0×10^2 (pH 7.8). The batch Kd values for F-1 alumina varied from 7.0×10^3 to 1.7×10^4, with a mean value of 1×10^4 (pH 7.9). The batch Kd values for BIOFIX varied from 1.8×10^4 to 3.3×10^4, with a mean value of 2.2×10^4 (pH 6.6-7.5). The batch Kd values for SORBPLUS varied from 2.7×10^5 to 2.7×10^6, with a mean value of 2.1×10^6 (pH 9.5 - 11.6). The batch Kd values generally decreased when the solution volume increased. This trend would be expected because there are more uranium atoms in the solution competing for the same adsorption sites.

The mean batch Kd values and pHs are shown in Table 2. The comparison of the mean batch Kd and RF values for the four favorable adsorbents are shown in Figure 1.

Table 2. Adsorption Experiments (Batch) Comparison for Uranium

Uranium-238 (ug/L)

Adsorbent	Mean Batch Kd	pH
Bone Charcoal	6.0×10^2 ml/g	7.8
F-1 Alumina	1.0×10^4 ml/g	7.9
BIOFIX	2.2×10^4 ml/g	6.6-7.5
SORBPLUS	2.1×10^6 ml/g	9.5 -11.6

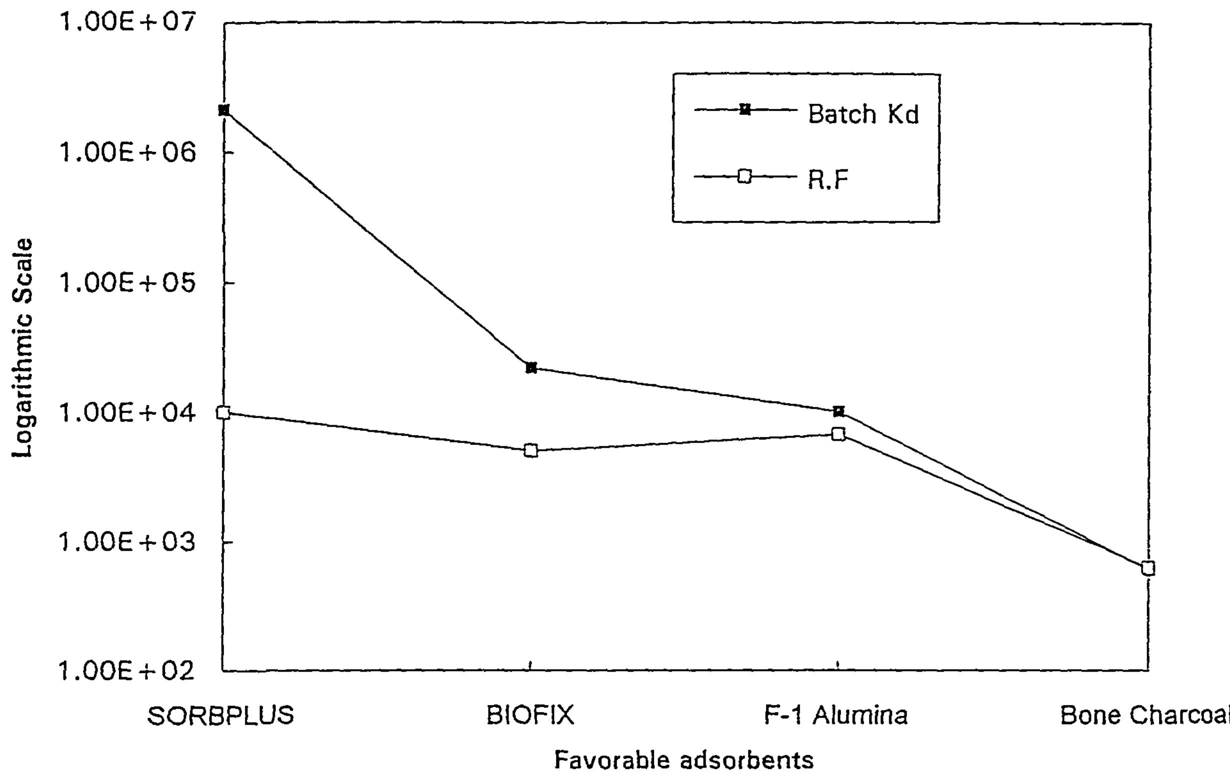

Figure 1. Batch Kd (ml/g) and Rentention Factor (R.F) Values for the Four Favorable Adsorbents

Equilibration relationships in adsorption process have been described by isotherm models such as Linear, Langmuir, Freundlich, and Modified Langmuir (Sparito, 1980; Polzer et al, 1985; 1992). using this approach, it was noted that F-1 alumina and BIOFIX exhibited a linear isotherm. A slope of this correlation yielded a batch Kd value, which was similar to the mean batch Kd value shown in Table 2. Bone charcoal and SORBPLUS showed a non-linear isotherm at the higher ratios. Their adsorption behavior followed Langmuir or Fruendlich or modified Langmuir isotherms.

CONCLUSION

Based on the column, batch, and pH considerations, F-1 Alumina and BIOFIX appear to be the best adsorbent for the effective (>99.9%) removal of uranium. SORBPLUS has the highest batch Kd value, but the effluent pH is high, which would require a neutralization step. A combination of SORBPLUS (5-10%) with F-1 Alumina or BIOFIX may be a viable option to achieve the maximum efficiency for uranium removal from Rocky Flats groundwater.

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