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Evaluation and Testing of HUMASORB-CS™ for the Removal of Radionuclides from Groundwater

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ABSTRACT

Groundwater remediation efforts are in progress for injection well waters at the Idaho National Engineering and Environmental Laboratory (INEEL) and other DOE sites.

An independent experiment to demonstrate the combined removal of the radionuclides, ^{85}Sr and ^{137}Cs from groundwater has been conducted with the sorbent, HUMASORB-CSTM. Arctech, Inc. manufactures this humic acid-based sorbent material. This sorbent material is reported to have potential for remediation of contaminated groundwater present at DOE sites. The purpose of this work was to evaluate the removal efficiency and the capacity of the sorbent.

Two ion-exchange columns were assembled at the Idaho Chemical Processing Plant (ICPP) to evaluate the sorbent technology. Columns 24.5 mm in diameter and 20 cm high were provided by Arctech. Approximately 50 liters of ICPP raw water spiked with ^{137}Cs and ^{85}Sr were processed through the columns at 6 mLs/min (3.6 bed volumes/hr.).

Initial ^{137}Cs breakthrough in both columns was observed after 22.0 and 30.2 bed volumes, respectively. Strontium-85 removal was slightly more efficient than ^{137}Cs removal. Initial ^{85}Sr breakthrough in both columns was observed after 29.4 and 22.7 bed volumes, respectively.

Calcium, which is of concern, is the major constituent within the feed solution. Calcium is attributed to loading interference in addition to other alkaline and alkaline earth metals such as stable Sr, Mg, Na, K, and Ba. Interfering ions fill exchange sites that greatly reduce the sorbents efficiency to sorb targeted ions such as radioactive Cs and Sr. Despite high concentrations of Ca in the feed solution, Ca was not sorbed by HUMASORB-CSTM. Magnesium, like calcium is normally attributed to loading interference, however, Mg was sorbed on the matrix. Fifty-percent breakthrough for column 1 and 3 was observed at 92 and 85 bed volumes, respectively. Barium was quantitatively sorbed by the sorbent material. Despite relatively high concentrations of Ba within the feed solution, Ba was never detected in the effluent samples. Initial Sr breakthrough for both columns were observed at 22 and 29 bed volumes, respectively. Strontium never exceeded 50% breakthrough throughout the test.

Results indicate HUMASORB-CS does not sorb sodium or potassium. Sodium and potassium concentrations were consistently observed at 100% breakthrough throughout the test.

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CONTENTS

ABSTRACT	iii
ACKNOWLEDGEMENTS.....	iv
CONTENTS	v
LIST OF TABLES	vi
LIST OF FIGURES	vi
INTRODUCTION	1
MATERIAL TESTED	2
EXPERIMENTAL	3
Column Preparation	4
Sampling and Analysis	5
RAW WATER COMPOSITION	7
RESULTS AND DISCUSSION	9
Strontium Loading Comparison	9
Cesium Loading Comparison	10
TAN Groundwater Prediction	11
Loading Interference	13
Sorbent Capacity Comparisons	16
CONCLUSIONS	19
REFERENCES	20
APPENDIX: EXPERIMENTAL DATA	21

LIST OF TABLES

Table 1. Properties of the HUMASORB-CS™ adsorbent	3
Table 2. Equipment list for the ion exchange apparatus	4
Table 3. ICPP raw water composition	8
Table 4. Cs sorbent capacity comparisons using HUMASORB-CS™ and IONSIV IE-911	17
Table 5. Sr sorbent capacity comparisons using HUMASORB-CS™ and IONSIV IE-911	18

LIST OF FIGURES

Figure 1. Schematic of the ion exchange apparatus	6
Figure 2. Ion exchange apparatus installed at the ICPP (photo)	6
Figure 3. Strontium-85 breakthrough comparisons for HUMASORB-CS™ with ICPP raw water	9
Figure 4. Cesium-137 breakthrough comparisons for HUMASORB-CS™ with ICPP raw water	10
Figure 5. Predicted Sr breakthrough for HUMASORB-CS™ and TAN groundwater	12
Figure 6. Predicted Cs breakthrough for HUMASORB-CS™ and TAN groundwater	13
Figure 7. Loading interference for column #1, stable Sr, Ca, Mg, Na, and K	14
Figure 8. Loading interference for column #3, stable Sr, Ca, Mg, Na, and K	15

Evaluation and Testing of HUMASORB-CS™ for the Removal of Radionuclides from Groundwater

INTRODUCTION

Groundwater remediation efforts are currently underway at the Idaho National Engineering and Environmental Laboratory (INEEL) in addition to numerous other DOE sites. Remediation efforts at the INEEL are primarily focused on the Groundwater Treatment Facility (GWTF) near the TSF-05 injection well located at Test Area North (TAN). The Separations Technology Development Group at Lockheed Martin Idaho Technologies Company has evaluated a variety of ion exchange materials for the removal of radioactive contaminants from groundwater (1,2). Other sites have also evaluated a number of ion exchange materials for removing radioactive contaminants from various water sources (3-6).

Several of the sorbent materials that have been tested for groundwater applications, are inorganic materials that have been incorporated within a web structure or an engineered support for column operation. Sorbents such as SELION CsTreat®, Sodium Titanate and IONSIV IE-911(Crystalline Silicotitanate) appear to be extremely effective in the sorption of specific radionuclides (1). In a test with actual GWTF groundwater the SELION CsTreat® processed ~2400 bed volumes of water while the IONSIV IE-911 processed ~1400 bed volumes of water. Cs-137 breakthrough was not observed in either of these materials, through the duration of the test. The IONSIV IE-911 material was also highly effective at removing strontium from the GWTF groundwater.

The fundamental difference of the HUMASORB-CS™ technology is that it is an organic sorbent material. Once loaded, the sorbent material is reported to be regenerable, however, regeneration properties of HUMASORB-CS™ were not demonstrated as part of this testing.

This report summarizes testing to determine the performance of HUMASORB-CS™ in removing trace quantities of ⁸⁵Sr and ¹³⁷Cs from simulated groundwater. The experimental objective of this work was to determine the removal efficiency, sorption behavior and capacity of the sorbent material for groundwater remediation efforts.

MATERIAL TESTED

HUMASORB-CS™, manufactured by Arctech Inc. is an ion exchange sorbent designed to remove metals, radionuclides and organic contaminants from aqueous wastes. HUMASORB-CS™ is a proprietary polymer based upon the organic structure of humic acid and consists of a mixture of molecular units.

Humic acid is that fraction of soil organic matter, which is not soluble in water under acidic ($\text{pH} < 2$) conditions, but is soluble at higher pH values. Humic acid consists of an aromatic macromolecule with various linkages between the aromatic groups. Various compounds are involved in the polymerization, including amino acids, amino sugars, peptides, aliphatic acids, and other aliphatic compounds.

EXPERIMENTAL

Two ion-exchange columns were assembled at the Idaho Chemical Processing Plant (ICPP) to evaluate the sorbent technology. Columns 24.5 mm in diameter and 20 cm high were provided by Arctech. Due to time constraints, it was determined that both columns would be operated at the same flow-rate. The data from each column would then act as a control for the other. This provided accuracy comparisons among the two columns.

To distinguish between the columns, they were appropriately labeled Column 1, and Column 3, referring to the labels on the HUMASORB-CS™ bottles, as provided by Arctech. The properties of the sorbent material are listed in Table 1.

Table 1. Properties of the HUMASORB-CS™ adsorbent.

Property	Column #1	Column #3
Adsorbent	HUMASORB-CS™	HUMASORB-CS™
Sorbent Supplier	Arctech, Inc.	Arctech, Inc.
Adsorbent Wt. (grams) (Dry Basis)*	35 grams	35 grams
Column Dimensions	24.5 mm diameter 20 cm high	24.5 mm diameter 20 cm high
Sorbent Bed Volume (Wet Basis)	~100 mL	~100 mL
Sorbent Bed Volume (Dry Basis)*	35 mL	35 mL

* Information provided by Arctech, Inc.

The test apparatus consisted of the equipment listed in Table 2. Two columns fabricated of glass and ¼ inch plastic tubing were provided by Arctech Inc. The columns were connected with appropriate tubing and fittings. Two positive displacement pumps at the front of each column were used to provide flow from the feed container. The system was designed for continuous

operation at a fixed flow rate. Two FMI stroke controllers provided a flowrate of approximately 6 mL/minute (3.6 bed volumes/hr) independently to each column. A process schematic of the assembled ion-exchange process is shown in Figure 1. Figure 2 displays the ion exchange set-up installed at the ICPP.

Table 2. Equipment list for the ion exchange apparatus.

Equipment	Description	Purpose
Feed Pump	Fluid Metering, Inc. Valveless metering pump Model # QVG-50	Supply feed water to ion exchange columns
Stroke Control	FMI stroke controller model #V200	Provide constant flowrate
Columns	24.5 mm diameter 20 cm high	Contain sorbent material

Column Preparation

To minimize material loss during the test, a portion of glass wool was placed at the bottom of each column to create a fixed bed. Wet HUMASORB-CS™ (35 grams on a dry basis prepared by Arctech Inc.) was transferred quantitatively from the bottles into each column. Visual inspection of each column was performed to verify uniform distribution.

HUMASORB-CS™, as described by Arctech Inc., approximately triples in volume when wet, as compared to a dry-basis. Column bed volumes (wet) of HUMASORB-CS™ of approximately 100 mL were observed in each column before testing. To remain consistent with other sorbent testing performed at DOE sites, bed volume calculations were determined on a wet basis (7,8,10). In this experiment, all bed volume calculations are based on a 100 mL wet bed volume basis.

Pretreatment of the HUMASORB-CS™ was performed before testing. An unascertained concentration of stable strontium was known to exist within the sorbent material. A one-liter bottle of deionized water was processed through each column to rinse existing stable strontium

from the sorbent material. Pretreatment was performed to increase the ability of the sorbent to exchange with ions in solution. It does this by removing impurities or unwanted ions from the active sites and filling the exchange sites with material that more readily exchanges with the targeted ions.

Sampling and Analysis

The columns were operated continuously for 63.7 hours. The average flowrate for each column during the course of the experiment was 6 mL/min (3.6 bed volumes/hr.). Approximately 46.9 L (~235 bed volumes per column) of raw water were processed.

Samples taken during the HUMASORB-CS testing were analyzed for ^{137}Cs , ^{85}Sr , total Sr, K, Na, Ba, Ca, Mg and pH. The solution exiting the column was collected in 1-liter polyethylene bottles for approximately 120 minutes.

Total Sr, Ba, Ca, Mg, Na, and K; were analyzed from 10-mL aliquots taken from each 1-liter effluent sample. The 10-mL aliquots were placed in polyethylene sample bottles and delivered to the Spectrochemistry Group for analysis. Total Sr, Ba, Ca, Mg, were analyzed using Inductively Coupled Plasma Atomic Emission Spectrophotometry (ICP-AES). Na, K were analyzed separately by Atomic Absorption Spectrophotometry (AAS). ^{137}Cs and ^{85}Sr activities were determined by Gamma Spectrometry from 1-mL aliquots also taken from each 1-liter effluent sample. The 1-mL aliquots were placed in glass sample bottles and delivered to the Radiochemistry Group for analysis.

After the smaller aliquots were collected, the remaining volume from each 1-liter sample bottle was recorded. The recorded volume was used to calculate the cumulative volume. Flowrate was recorded by measuring the volume of the collected sample and the time used to collect the sample.

Figure 1. Schematic of the ion exchange apparatus.

Figure 2. Ion exchange apparatus installed at the ICPP.

RAW WATER COMPOSITION

Raw water was used as the feed solution for the HUMASORB-CS™ ion exchange test. Approximately 50 liters of raw water were obtained from a well at the Idaho Chemical Processing Plant (ICPP), from an approximate depth of 600 feet. Initially, groundwater from the Groundwater Treatment Facility (GWTF) located at TAN, was to be tested. It became necessary to use the ICPP raw water due to time constraints in relation to the recent listing of the TAN groundwater as RCRA waste. ICPP groundwater is in essence very similar to TAN groundwater. It was very important to obtain similar groundwater feed samples for comparison of other sorbent materials tested at the INEEL (1,2,5).

Spikes of ^{137}Cs and ^{85}Sr were used to facilitate analytical measurements. Activities of ^{137}Cs and ^{85}Sr were 31.8 dps/mL and 84.5 dps/mL respectively. In order to attain accurate analytical results, groundwater used in this test was spiked with relatively high concentrations of ^{137}Cs and ^{85}Sr . Concentrations of ^{137}Cs were three orders of magnitude higher compared with other tests performed at the INEEL (1). Cesium concentrations at Test Area North (TAN) were $9.2 \times 10^{-14} \text{ M}$ compared to $7.21 \times 10^{-11} \text{ M}$ ^{137}Cs concentrations used in the HUMASORB-CS™ test. The total strontium concentrations in the HUMASORB-CS™ test were very similar to those concentrations found at TAN ($3.35 \times 10^{-6} \text{ M}$ vs. $3.4 \times 10^{-6} \text{ M}$).

On a mass basis, the difference in ^{137}Cs concentrations between the spiked raw water and the TAN groundwater is insignificant due to high concentrations of interfering ions such as, magnesium, barium, calcium and total strontium. Magnesium concentrations of $7 \times 10^{-4} \text{ M}$ in ICPP groundwater are 10 billion times higher than cesium concentrations in TAN groundwater. Barium concentrations of $1.6 \times 10^{-6} \text{ M}$ are also much higher than cesium concentrations used in the HUMASORB-CS™ test.

The presence of calcium, magnesium, barium and other divalent cations are of particular interest in this work. Divalent metals (interfering ions) have the ability to reduce the loading capacity of some sorbent materials. Known divalent metals within the HUMASORB-CS™ matrix are also of interest. These divalent metals could also reduce the loading capacity of the sorbent material. The composition of ICPP raw water is listed in Table 3.

Table 3. ICPP raw water composition.

Component	Units	Concentration
pH		7.8
SO ₄ ⁻²	mg/L	25.5
HCO ₃ ⁻	mg/L	89
Aluminum	mg/L	< 0.02
Barium	mg/L	0.215
Cadmium	mg/L	< 0.004
Calcium	mg/L	49
Copper	mg/L	<0.003
Iron	mg/L	<0.024
Lead	mg/L	0.04
Magnesium	mg/L	15.8
Manganese	mg/L	< 0.004
Phosphorus	mg/L	0.04
Potassium	mg/L	2.59
Silicon	mg/L	11.6
Sodium	mg/L	8.32
Zinc	mg/L	0.065
Strontium	mg/L	0.292
Cesium-137	dps/mL	~31.8
Strontium-85	dps/mL	~84.5

RESULTS AND DISCUSSION

Strontium Loading Comparison

Figure 3 displays results for the removal of ^{85}Sr from groundwater. The percent breakthrough ($C/C_0 \times 100$) is plotted against the bed volumes of solution passed through the column. Initial ^{85}Sr breakthrough in columns 1 and 3 was observed after 22.7 and 29.4 bed volumes, respectively. The feed solution was exhausted before complete breakthrough was reached. Fifty-percent breakthrough was never observed during the test. Despite large concentrations of Ca found in the feed solution and within the sorbent matrix, sorption of ^{85}Sr does not appear to be influenced by the presence of Ca.

Figure 3. Strontium-85 breakthrough comparisons for HUMASORB-CSTM with ICPP raw water.

Cesium Loading Comparisons

Figure 4 displays results for the removal of ^{137}Cs from groundwater. The percent breakthrough ($C/\text{Co} \times 100$) is plotted against the bed volumes of solution passed through the column. Initial ^{137}Cs breakthrough in columns 1 and 3 was observed after 22.0 and 7.6 bed volumes respectively. Fifty-percent breakthrough occurred after 93.9 and 70.3 bed volumes. One hundred percent breakthrough was achieved by column 3, occurring at 168.9 bed volumes, while column 1, attained a maximum breakthrough of 94.7%

Figure 4. Cesium-137 breakthrough comparisons for HUMASORB-CS™ with ICPP raw water.

TAN Groundwater Prediction

Utilizing TAN, TSF-05 injection well groundwater concentrations for strontium and cesium, two graphs were constructed displaying strontium and cesium concentrations plotted against the cumulative bed volume. Also provided are the EPA drinking water standards for strontium-90 and cesium-137 of 8 pCi/L and 119 pCi/L respectively. These standards are the current limits used at TAN for groundwater discharge back to the environment.

To predict TAN strontium and cesium concentrations in pCi/L, breakthrough values ($C/C_0 \times 100$) from the HUMASORB-CS™ test were multiplied by the strontium and cesium concentrations found in the feed solution at TAN, and then divided by 100%. This calculation provides an estimated number of bed volumes that could be processed before column effluents exceeded EPA drinking water standards using TAN ground water.

Effluent streams from the HUMASORB-CS™ sorbent material would either meet or exceed the EPA drinking water limit for strontium between 52 and 63 bed volumes, respectively. Effluent streams from the HUMASORB-CS™ sorbent material would either meet or exceed the EPA drinking water limit for cesium between 36 and 58 bed volumes, respectively. Figures 5 and 6 display the predicted breakthrough for TAN groundwater.

Other sorbent materials previously tested with groundwater, efficiently sorbed Sr and Cs from the contaminated groundwater. A column test using IONSIV IE-911 was performed by Sandia National Laboratories, using a feed solution simulating contaminated TAN groundwater. Cesium and strontium concentrations were 0.0497 ppm and 0.355 ppm, respectively. The cesium concentration in the Sandia test was four orders of magnitude higher than the concentration used in the HUMASORB-CS™ test. These high concentrations were added to Sandia simulated TAN groundwater in order to facilitate analysis.

The test was terminated after 4550 bed volumes had been passed through the column at a flowrate of 10 bed volumes/hr. No cesium or strontium was ever detected in the effluent stream. The detection limits were approximately 0.08 ppb for Cs, and 0.2 ppb for Sr. Concentrations for both cesium and strontium never exceeded the EPA drinking water standard of 8 pCi/L and 119 pCi/L (9).

Another test performed at the INEEL using IONSIV IE-911, processed 1200 bed volumes of actual TAN groundwater through the column in which strontium and cesium breakthrough was never observed during the test. Concentrations for both strontium and cesium never exceeded the EPA drinking water standard of 8 pCi/L and 119 pCi/L (1).

Figure 5. Predicted Sr breakthrough for HUMASORB-CS™ and TAN groundwater.

Figure 6. Predicted Cs breakthrough for HUMASORB-CS™ and TAN groundwater.

Loading Interference

Figures 7 and 8 display the HUMASORB-CS™ results for the removal of stable strontium, calcium, magnesium, sodium and potassium from ICPP groundwater.

Calcium, which is of concern, is the major constituent within the feed solution, at a concentration of 49 mg/L. Calcium can be attributed to loading interference in respect to targeted ions, such as ^{85}Sr and ^{137}Cs . Calcium concentrations in the effluent exceed the input value throughout the test. Initial Ca concentrations of 176.7% and 181.1% are observed at 22.0 and 30.2 bed volumes, respectively. Higher Ca concentrations than those found within the feed solution can be attributed to Ca being eluted from the column. However, it appears that Ca is not adsorbed by HUMASORB-CS™.

Magnesium concentrations within the feed solution are observed in relatively high concentrations of 15.8 mg/L. Magnesium, like calcium, is normally attributed to loading interference. Magnesium, however, is not displaced and is loaded on the HUMASORB-CS™ column. Magnesium breakthrough results for HUMASORB-CS™ are shown in Figures 7 and 8. Initial breakthrough for column 1 and 3 is observed at 7.4 and 7.6 bed volumes, respectively. Fifty- percent breakthrough occurs at 92 and 85 bed volumes, respectively.

Figure 7. Loading interference for column #1, stable Sr, Ca, Mg, Na, and K.

It appears that initial column preparation, a process of rinsing stable strontium from the column with deionized water, was not entirely effective. Stable strontium is observed in relatively high concentrations at approximately 14.7 bed volumes.

Early breakthrough in addition to small concentration undulations can be attributed to concentrations of stable strontium within the sorbent matrix, much like calcium. Despite large

concentrations of Ca, Mg and Ba, both radioactive and stable strontium never exceed 50% breakthrough. It is interesting to note that both stable and radioactive strontium concentrations never converge during the test, indicating that steady state column operation was never established.

Figure 8. Loading interference for column #3, stable Sr, Ca, Mg, Na, and K.

Barium concentrations of 0.215 mg/L were observed in the feed solution. Nevertheless, Ba was never detected in the effluent samples. Barium is quantitatively sorbed by the exchange material in addition to the other metals, Sr, and Mg. A breakthrough curve could not be prepared due to the small amount of barium observed in the column effluent (i.e. ~100% removal) throughout the duration of the test.

Initial results indicate HUMASORB-CS™ does not sorb sodium or potassium. Sodium is initially loaded on the HUMASORB-CS™ sorbent for the first 14.7 and 15.1 bed volumes. Sodium concentrations exceed the input value of 8.32 mg/L, at 29.4 and 15.1, bed volumes indicating either the presence of sodium within the sorbent matrix or a displacement by a more strongly bound ion. During the remainder of the test, sodium maintains 100% breakthrough,

indicating it is no longer sorbed. Sodium concentrations in the effluent exceed the feed concentrations, possibly indicating the presence of small amounts of sodium within the sorbent matrix being released in the effluent.

Initial potassium breakthrough ($C/Co \times 100$) for columns 1 and 3 is 482% and 401% of the input value. High levels of potassium in the column effluent indicate a presence within the sorbent matrix being eluted from the column. After 29.4 and 37.5 bed volumes, potassium maintains approximately 100% breakthrough throughout the remainder of the test.

A pH value of 7.98 was detected in the feed solution before testing. Initial pH values for columns 1 and 3 were 7.88 and 8.10 respectively. In columns 1 and 3, pH values varied between 7.56, 8.11, 7.49, and 8.10, respectively.

Sorbent Capacity Comparisons

The results from the HUMASORB-CS™ test and the test performed at Sandia National Laboratory were used to estimate the cesium removal by HUMASORB-CS™ compared with removal by IONSIV IE-911. The total cesium adsorbed (based on the volume of contaminated water treated before cesium was detected in the effluent) by the two sorbents and the cesium adsorbed per gram of the sorbent (using the quantity of sorbents used in the tests) are shown in Table 4.

The results in Table 4 indicate that IONSIV IE-911 has a much higher capacity than HUMASORB-CS™ for cesium removal. The amount of cesium adsorbed per gram of IONSIV IE-911 is nearly six orders of magnitude higher than that adsorbed by HUMASORB-CS™. The cesium concentration in the Sandia simulated TAN groundwater used in the IONSIV IE-911 test was nearly four orders of magnitude higher than that used in the HUMASORB-CS™ performed at the INEEL.

Table 4. Cs sorbent capacity comparisons using HUMASORB-CS™ and IONSIV IE-911

	HUMASORB-CS		IONSIV IE-911 (CST)
	Column # 1	Column # 3	
Cs Input	8.59×10^5 pCi/L	8.59×10^5 pCi/L	50 ppb
Cs Input gm-moles/L	7.21×10^{-11}	7.21×10^{-11}	3.7×10^{-7}
Cs adsorbed (Total) gm-moles	1.05×10^{-10} At 14.7 bed vol.	1.63×10^{-10} At 22.7 bed vol.	5.05×10^{-6} At 4550 bed vol.
Cs adsorbed per gram sorbent, gm-moles/gm	3.04×10^{-12} 35 grams dry sorbent	4.67×10^{-12} 35 grams dry sorbent	1.68×10^{-6} 3 grams dry sorbent

A similar comparison using the results from the HUMASORB-CS™ test and the test performed at Sandia National Laboratory were used to estimate the strontium removal by HUMASORB-CS™ compared with removal by IONSIV IE-911. The total strontium adsorbed (based on the volume of contaminated water treated before strontium was detected in the effluent) by the two sorbents and the strontium adsorbed per gram of the sorbent (using the quantity of sorbents used in the tests) are shown in Table 5.

The results in Table 5 indicate that IONSIV IE-911 has a higher capacity than HUMASORB-CS™ for strontium removal. The amount of strontium adsorbed per gram of IONSIV IE-911 is nearly two orders of magnitude higher than that adsorbed by HUMASORB-CS™. The strontium concentrations in the Sandia simulated TAN groundwater used in the IONSIV IE-911 test were very similar to those used in the HUMASORB-CS™ test performed at the INEEL.

Table 5. Sr sorbent capacity comparisons using HUMASORB-CS™ and IONSIV IE-911

	HUMASORB-CS		IONSIV IE-911 (CST)
	Column # 1	Column # 3	
Sr Input	292 ppb	292 ppb	355 ppb
Sr Input gm-moles/L	3.31×10^{-6}	3.31×10^{-6}	4.03×10^{-6}
Sr adsorbed (Total) gm-moles	4.87×10^{-6} At 14.7 bed vol.	4.97×10^{-6} At 15.0 bed vol.	5.50×10^{-5} At 4550 bed vol.
Sr adsorbed per gram sorbent, gm-moles/gm	1.42×10^{-7} 35 grams dry sorbent	1.39×10^{-7} 35 grams dry sorbent	1.83×10^{-5} 3 grams sorbent

It should be noted that sorbent capacity should be determined from batch contact experiments rather than column tests. In column tests, equilibrium between the solid and liquid phases is not established. Sorbent capacity measured at extremely low liquid ion concentrations will be a function of concentration until excess ions are in solution and not sorbed onto the solid phase at equilibrium.

The results in Tables 4 and 5 are shown to provide a relative comparison of sorbent capacities for HUMASORB-CS™ and IONSIV IE-911 under dynamic conditions. These numbers do not represent maximum capacities for either sorbent.

CONCLUSIONS

The evaluation of HUMASORB-CS™ as a sorbent material for the removal of radionuclides from groundwater is presented in the following conclusions.

- HUMASORB-CS™ does not effectively sorb Cs. Cesium breakthrough was observed after 22.0 and 7.6 bed volumes on a wet bed volume basis. Fifty- percent breakthrough occurred after 93.9 and 70.3 bed volumes, respectively. Using TAN groundwater concentrations, effluent streams from the HUMASORB-CS™ sorbent material would either meet or exceed the EPA drinking water limit of 119 pCi/L for Cs between 36 and 58 bed volumes.
- HUMASORB-CS™ exhibits partial effectiveness in the sorption of Sr. Initial strontium breakthrough was observed in column 1 and 3 after 22.7 and 29.4 bed volumes, respectively. Fifty-percent breakthrough was never observed during the test, however, small concentrations of stable strontium within the sorbent matrix, most certainly reduce the capacity of the sorbent material. Using TAN groundwater concentrations, effluent streams from the HUMASORB-CS™ sorbent material would either meet or exceed the EPA drinking water limit of 8 pCi/L for Sr between 52 and 63 bed volumes.
- HUMASORB-CS™ exhibits a high affinity for interfering ions, Sr, Mg and Ba. Therefore, the majority of the materials ion exchange capacity is consumed with these ions. Magnesium and barium are in concentrations many magnitudes higher than targeted ions such as radioactive Cs and Sr.
- The data presented in this report are useful for the comparison of HUMASORB-CS™ with other potential sorbent materials to remove radionuclides from groundwater. The data indicate that, due to the materials low capacity and selectivity, HUMASORB-CS™ is not sufficiently effective for Cs and Sr removal from groundwater, and does not warrant further testing, for this application.

REFERENCES

1. Garn, T. G., Brewer, K. N., Tillitson, R. D., Todd, T. A., "Demonstration of Various Ion Exchange Sorbents for the Removal of Cesium and Strontium from TAN Groundwater", INEL/EXT-97-00825, August 1997
2. Herbst, R. S., Brewer, K. N., Todd, T. A., "Decontamination of TAN Injection Well Waters Using 3M Web Technology", INEL-95/0589, November 1995
3. Brown, G. N., Bontha, J.R., Carson, K. J., Elovich, R. J., DesChane, J. R., "Comparison of Inorganic Ion Exchange Materials for Removing Cesium, Strontium, and Transuranic Elements for K-Basin Water", PNNL-11746 (UC-2030), October 1997
4. Brown, G. N., Carson, K. J., DesChane, J. R., Elovich, R. J., "Performance Evaluation of 24 Ion Exchange Materials for Removing Cesium and Strontium from Actual and Simulated N-Reactor Storage Basin Water", PNNL-11711 (UC-2030), September 1997
5. MSE Technology Applications, Inc., "Final Report-Applications of Selective Polymer Separations Project Laboratory Testing at INEEL", HMP-31, November 1997
6. Bechtel Hanford, Inc., "Demonstration of Radionuclides Removal at the 105-N Basin Using the 3M System", BHI-00759, Rev.0, 1996
7. Brown, G. N., Bontha, J. R., Carlson, C. D., DesChane, J. R., Elovich, R. J., Kurath, D. E., Tanaka, P. K., Edmonson, D. W., Herting, D. L., Smith, J.R., "Ion Exchange Removal of Cesium from Simulated and Actual Supernate from Hanford Tanks 241-SY-101 and 241-Sy-103", PNI-10792 (UC-721), September 1995
8. Schroeder, N. C., "Technetium Partitioning for the Hanford Tank Waste Remediation System: Sorption of Technetium from DSS and DSSF-7 Waste Simulants Using Reillex™-HPQ Resin", LAUR-95-40, January 6, 1995
9. Miller, J. E., Brown, N. E., "Development and Properties of Crystalline Silicotitanate (CST) Ion Exchangers for Radioactive Waste Applications", SAND97-0771 (UC-721, UC-510), April 1997
10. Lee, D. D., Travis, J. R., Gibson, M. R., "Hot Demonstration of Proposed Commercial Cesium Removal Technology", ORNL/TM-13169, December 1997

APPENDIX: EXPERIMENTAL DATA

INEEL TEST 9/29/97 TO 10/02/97
HUMASORB-CS Bed Volume (35 grams)
Column #1

DATE	TIME	FRACTION TIME (min)	VOLUME mL/min	CUM. VOL.	CUM. BED VOL. *	FLOWRATE mL/min	SAMPLE FRACTION	Feed Conc. d/s/ml		Feed Conc. ug/ml						pH	Percent Breakthrough C/Co							
								Cs-137 d/s/ml	Sr-85 d/s/ml	Ca ug/ml	Mg ug/ml	Stable Sr ug/ml	Ba ug/ml	K ug/ml	Na ug/ml		Cs-137 C/Co	Sr-85 C/Co	Ca C/Co	Mg C/Co	Stable Sr C/Co	Ba C/Co	K C/Co	Na C/Co
								31.8	84.5	49.14	14.57	0.30	0.14	2.24	7.32		7.98							
9/29/97	2:27pm	120	744	744	7.44	6.20	1-1			68.75	0.23	0.08	0.0228	10.8	4.2	7.88			140.02	1.58	25.81		482.14	57.38
9/29/97	4:27	120	730	1474	14.74	6.08	1-2			81.54	0.43	0.10		4.9	7.28	7.94			166.06	2.93	34.15		218.75	99.45
9/29/97	6:27	120	728	2202	22.02	6.07	1-3			86.79	0.82	0.10		2.84	6.56	8.11	2.3		176.75	5.64	34.15		126.79	89.62
9/29/97	8:27	123	738	2940	29.40	6.00	1-4	2.21	1.09	84.57	1.27	0.10		2.22	8	7.9	3.6	1.0	172.22	8.72	33.33		99.11	109.29
9/29/97	10:30	120	730	3670	36.70	6.08	1-5	3.59	0.81	81.04	1.76	0.10		2.34	6.82	7.82	4.9		165.04	12.05	30.69		104.46	93.17
9/30/97	12:30am	240	1470	5140	51.40	6.13	1-6	3.83	2.81	78.73	2.91	0.09		1.81	6.86	7.71	9.5		160.33	19.99	30.28		80.80	93.72
9/30/97	4:30	180	1104	6244	62.44	6.13	1-7	5.98	3.82	72.60	4.52	0.09		2.07	6.91	7.62	13.9	2.9	147.84	31.02	29.07		92.41	94.40
9/30/97	7:30	120	732	6976	69.76	6.10	1-8	8.86	5.45	72.89	5.85	0.09		2.44	8.05	7.72	19.2	3.9	148.44	40.12	29.47		108.93	109.97
9/30/97	9:30	120	728	7704	77.04	6.07	1-9	11.3	5.45	72.77	6.32	0.10		2.6	8.25	7.81	24.4	3.8	148.19	43.35	30.49		116.07	112.70
9/30/97	11:30	120	728	8432	84.32	6.07	1-10	13.4	6.75	70.41	6.65	0.10		2.04	8.07	7.57	34.9	4.5	143.40	45.66	31.91		91.07	110.25
9/30/97	1:30pm	120	738	9170	91.70	6.15	1-11	16	7.05	73.33	7.24	0.11		1.98	7.89	7.62	42.8	5.2	149.34	49.65	32.93		88.39	107.79
9/30/97	3:30	120	733	9903	99.03	6.11	1-12	21.3	8.75	72.30	7.87	0.11	0.0216	1.9	8.34	7.62	56.9	6.8	147.24	54.01	37.80		84.82	113.93
9/30/97	5:30	120	737	10640	106.40	6.14	1-13	21	8.33	71.34	8.48	0.11		2.52	7.27	7.56	64.8	7.8	145.28	58.17	35.16		112.50	99.32
9/30/97	7:43	107	662	11302	113.02	6.19	**1-14	17.4	8.89	70.08	8.72	0.11		2.18	7.17	7.57	48.7	7.5	142.71	59.82	35.16		97.32	97.95
9/30/97	9:30	120	728	12030	120.30	6.07	1-15	18	9.15	68.21	9.32	0.10		2.38	8.23	7.69	56.9	8.3	138.91	63.98	33.13		106.25	112.43
9/30/97	11:30	128	780	12810	128.10	6.09	1-16	20.2	11.4								88.4	12.0						
10/1/97	1:38am	292	1788	14598	145.98	6.12	1-17	16	10.8								55.0	12.0						
10/1/97	6:30	120	730	15328	153.28	6.08	1-18	15.3	12					1.82	7.78	7.58	54.1	12.2				81.25	106.28	
10/1/97	8:30	120	730	16058	160.58	6.08	1-19	19.4	13.7	61.09	11.35	0.11					66.4	14.7	124.41	77.85	32.72			
10/1/97	10:30	120	732	16790	167.90	6.10	1-20	24	16.3								81.1	16.0						
10/1/97	12:30	120	730	17520	175.20	6.08	1-21	24.6	14.3					2.08	7.47	7.72	84.0	15.5				92.86	102.05	
10/1/97	2:30pm	120	730	18250	182.50	6.08	1-22	29.3	16.1	62.96	12.15	0.13					94.7	17.2	128.21	83.37	37.40			
10/1/97	4:30	120	734	18984	189.84	6.11	1-23	32.1	18.7								89.6	17.2						
10/1/97	6:30	120	738	19722	197.22	6.15	1-24	29.1	19.4					2.59	7.04	7.79	90.6	19.8				115.63	96.17	
10/1/97	8:30	120	729	20451	204.51	6.07	1-25	26.6	19.9	62.22	12.63	0.13					87.1	21.5	126.72	86.66	41.26			
10/1/97	10:30	120	725	21176	211.76	6.05	1-26	24.2	20.3								76.4	21.9						
10/2/97	12:30am	300	1820	22996	229.96	6.07	1-27	25.5	23					2.24	7.26	7.7	75.5	25.7				100.00	99.18	
10/2/97	5:30	~62	375	23371	233.71	6.06	1-28	25.7	24.9	60.44	14.21	0.13					83.6	25.7	123.08	97.49	43.90			

INEEL TEST 9/29/29 TO 10/02/97
HUMASORB-CS Bed Volume (35 grams)
Column #3

DATE	TIME	FRACTION TIME (min)	VOL. mL/min	CUM. VOLUME	CUM. BED VOL. *	FLOWRATE mL/min	SAMPLE FRACTION	Feed Conc. D/s/ml		Feed Conc. ug/ml								Percent Breakthrough C/Co											
								Cs-137 d/s/mL	Sr-85 d/s/mL	Ca ug/ml	Mg ug/ml	Stable Sr ug/ml	Ba ug/ml	K ug/ml	Na ug/ml	pH	Cs-137 C/Co	Sr-85 C/Co	Ca C/Co	Mg C/Co	Sr-85 C/Co	Ba C/Co	K C/Co	Na C/Co					
								31.80	84.50	49.10	14.57	0.30	0.14	2.24	7.32	7.98													
9/29/97	2:27pm	120	760	760	7.60	6.33	3-1			70.08	0.28	0.08		8.98	5.17	8.10													
9/29/97	4:27	120	747	1507	15.07	6.23	3-2			81.92	0.76	0.10		3.68	8.44	7.78			166.83	5.24	33.33				164.29	115.30			
9/29/97	6:27	120	763	2270	22.70	6.36	3-3			85.20	1.12	0.10		2.61	8.41	8.07			173.50	7.67	33.94				116.52	114.89			
9/29/97	8:27	123	751	3021	30.21	6.11	3-4	2.21	1.09	88.94	1.85	0.10		2.68	7.79	7.85	6.95	1.36	181.12	12.70	33.13				119.64	106.42			
9/29/97	10:30	120	733	3754	37.54	6.08	3-5		3.59	86.56	2.66	0.10		2.26	7.52	7.78	11.29	0.96	176.28	18.24	32.32				100.89	102.73			
9/30/97	12:30am	240	1470	5224	52.24	6.12	3-6		3.83	82.68	3.71	0.09		2.40	7.77	7.80	12.04	3.33	168.37	25.48	31.10				107.14	106.15			
9/30/97	4:30	180	1100	6324	63.24	6.11	3-7		5.98	80.12	5.37	0.09		2.15	7.63	7.77	18.81	4.52	183.15	36.87	31.10				95.98	104.23			
9/30/97	7:30	120	742	7066	70.66	6.18	3-8		8.86	5.45	79.17	6.26	0.09		2.27	6.68	7.75	27.86	6.45	161.23	42.94	31.30				101.34	91.26		
9/30/97	9:40	110	673	7739	77.39	6.12	3-9		11.30	5.45	77.99	6.89	0.10		2.64	7.31	7.74	35.53	6.45	158.83	47.26	33.94				117.86	99.86		
9/30/97	11:30	120	735	8474	84.74	6.12	3-10		13.40	6.75	76.55	7.15	0.10		2.73	6.49	7.55	42.14	7.99	155.88	49.03	33.94				121.88	88.66		
9/30/97	1:30pm	120	738	9212	92.12	6.15	3-11		16.00	7.05	78.25	7.63	0.11		2.71	6.67	7.68	50.31	8.34	159.35	52.37	37.20				120.98	91.12		
9/30/97	3:30	120	750	9962	99.62	6.25	3-12		21.30	8.75	76.84	7.98	0.11		2.44	7.76	7.55	66.98	10.36	156.48	54.76	38.62				108.93	106.01		
9/30/97	5:30	120	749	10711	107.11	6.24	3-13		21.00	8.33	74.89	8.45	0.11		2.43	6.84	7.60	66.04	9.86	152.50	58.01	36.38				108.48	93.44		
9/30/97	7:43	107	668	11379	113.79	6.24	3-14		17.40	8.89	74.30	9.10	0.11		2.50	8.01	7.49	54.72	10.52	151.31	62.45	38.41				111.61	109.43		
9/30/97	9:30	120	732	12111	121.11	6.10	3-15		18.00	9.15	72.87	9.63	0.10		2.24	6.86	7.64	56.60	10.83	148.40	66.08	35.37				100.00	93.72		
9/30/97	11:30	128	780	12891	128.91	6.14	3-16		20.20	11.40								63.52	13.49										
10/1/97	1:38am	292	1798	14689	146.89	6.16	3-17		18.00	10.80								50.31	12.78										
10/1/97	6:30	120	732	15421	154.21	6.10	3-18		15.30	12.00					2.36	7.57	7.61	48.11	14.20						105.36	103.42			
10/1/97	8:30	120	736	16157	161.57	6.13	3-19		19.40	13.70	67.07	11.06	0.11					61.01	16.21	136.60	75.87	38.01							
10/1/97	10:30	120	738	16895	168.95	6.15	3-20		24.00	16.30								75.47	19.29										
10/1/97	12:30	120	732	17627	176.27	6.10	3-21		24.60	14.30					2.52	7.15	7.69	77.36	16.92						112.50	97.68			
10/1/97	2:30pm	120	736	18363	183.63	6.13	3-22		29.30	16.10	66.97	12.00	0.13					92.14	19.05	136.38	82.34	43.09							
10/1/97	4:30	120	735	19098	190.98	6.12	3-23		32.10	18.70								100.94	22.13										
10/1/97	6:30	120	740	19838	198.38	6.16	3-24		29.10	19.40					2.20	7.24	7.68	91.51	22.96						98.21	98.91			
10/1/97	8:30	120	734	20572	205.72	6.11	3-25		26.60	19.90	67.37	12.85	0.13					83.65	23.55	137.19	88.18	43.90							
10/1/97	10:30	120	740	21312	213.12	6.16	3-26		24.20	20.30								76.10	24.02										
10/2/97	12:30am	300	1840	23152	231.52	6.13	3-27		25.50	23.00					2.34	6.85	7.77	80.19	27.22						104.46	93.58			
10/2/97	5:30	~62min	380	23532	235.32	6.15	3-28		25.70	24.90	62.37	13.37	0.13					80.82	29.47	127.02	91.72	44.51							