UNIDIRECTIONAL CESIUM LOADING,
SCRUBBING AND ELUTION OF AW500
ZEOLITE COLUMNS

L. L. Ames, Jr.
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By

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ABSTRACT

Unidirectional flow operation of an AW500 synthetic zeolite column for cesium removal and recovery from Purex Alkaline Supernatant was shown to be feasible within the various flow rate ranges studied. The ranges included a downflow loading rate of 1.5 column volumes/hr, downflow scrubbing at 0.75 and 1.5 column volumes/hr with 0.2M $(\text{NH}_4)_2\text{CO}_3$ solution, and downflow elution at from 0.64 to 3.0 column volumes/hr with 2.0M NH_4OH + 3.0M $(\text{NH}_4)_2\text{CO}_3$ solution. Elution flow rates of more than 3 column volumes/hr were too rapid.

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UNIDIRECTIONAL CESIUM LOADING, SCRUBBING
AND ELUTION OF AW500 ZEOLITE COLUMNS

L. L. Ames, Jr. and B. W. Mercer

INTRODUCTION

An AW500 zeolite ion exchange column will be used to extract cesium radioisotopes from Purex Supernatant (PSN) and Purex Sludge Supernatant (PSS) waste solutions. The extraction process was broadly discussed in a previous report,⁽¹⁾ but several aspects of the process required further study. In general, a cesium removal cycle would consist of loading the AW500 column to 2 to 5% cesium breakthrough, scrubbing with relatively dilute ammonium carbonate solution to replace sodium and other cesium-adulterating cations, and eluting with a strong ammonium carbonate-ammonium hydroxide solution at 55 °C. A study was conducted to establish the feasibility of column loading, scrubbing and eluting of cesium in the same direction. The effects of column flow rate, column loading and feed composition on the rate and amount of sodium and cesium removal during the scrubbing operation, as well as the effects of flow rate and cesium loading on cesium elution, were included in the study. Also, the cation exchange performance of a Davison zeolite was compared to that of AW500.

The results of the study of the various effects on column performance are presented in this report.

SUMMARY AND CONCLUSIONS

Cesium loading, scrubbing and elution data indicated that unidirectional flow operation with AW500 columns was feasible within the various flow ranges studied. These

ranges included a downflow loading rate of 1.5 column volumes/hr, downflow scrubbing at 0.75 to 1.5 column volumes/hr, and downflow elution at from 0.64 to 3.0 column volumes/hr. A sodium-to-cesium ratio range of from 6300 to 42,400 did not appreciably affect the scrub cesium loss or sodium removal curves. There was evidence that elution flow rates of less than 3.0 column volumes/hr were desirable. The cation exchange kinetics of Davison 700 zeolite columns were too poor to allow use of the eight to twelve mesh 700 for an AW500 substitute.

DISCUSSION

METHODS OF INVESTIGATION

A column scrub statistical experimental design was used to obtain maximum information on the effects of column length, flow rate and sodium-to-cesium ratio in the loading solution on cesium losses and sodium removal. A two-level factorial design with synthetic PSN and PSS loading solutions representing low and high (6300 and 42,400) sodium-to-cesium ratios, respectively; AW500 columns of 35 and 50 cm length (both 3.8 cm diam); and column scrub flow rates of 0.75 and 1.5 column volumes/hr was devised and the experiments carried out. The design is diagrammatically represented in Figure 1. The PSN and PSS synthetic loading solution compositions were furnished by Atlantic Richfield Hanford Company and are given in Table I. The solution was filtered before use because an aluminosilicate precipitate formed in the PSS.

The long and short AW500 columns, containing 381 and 267 g, respectively, were loaded with PSS or PSN influent to 4% cesium breakthrough or less. All scrubbing was done with a 0.2M $(\text{NH}_4)_2\text{CO}_3$ solution at 23 °C. Instantaneous samples were obtained at each column volume of scrub effluent, analyzed for sodium on the flame photometer and counted for ^{137}Cs content.

Flow Rate, column volumes/hr		Sodium-to-Cesium Loading Ratio			
		(PSN) 6300		(PSS) 42,400	
		Column Length, cm			
		35	50	35	50
0.75		1	3	2	4
1.50		5	7	6	8

FIGURE 1. Two-level Factorial Design Used in the Column Scrub Experiments. (The numbers identify treatment combinations, and each represents a column experiment.)

TABLE I. Chemical Composition of PSS and PSN

PSS (3.79M Na)		PSN (5.14M Na)	
Constituent	Molarity	Constituent	Molarity
NaNO ₃	0.92	NaNO ₂	2.78
Na ₂ CO ₃	0.71	Na ₂ CO ₃	0.73
NaNO ₂	0.47	NaNO ₃	0.52
Na ₂ SO ₄	0.37	Na ₂ SO ₄	0.133
NaOH	0.078	NaCl	0.078
NaAlO ₂	0.046	Na ₃ PO ₄	0.013
Na ₃ PO ₄	0.031	CsCl	8.14 x 10 ⁻⁴
NaCrO ₄	0.008	¹³⁷ Cs	trace
Na ₂ SiO ₃	0.005		
NaCl	0.002		
CsCl	8.95 x 10 ⁻⁵		
¹³⁷ Cs	trace		

With no intervening water wash, the scrubbed columns were eluted at 55 °C and 1.5 and 0.75 column volumes/hr with a 2.0M NH_4OH + 3.0M $(\text{NH}_4)_2\text{CO}_3$ solution. Each column volume of elution effluent was collected in its entirety and analyzed for ^{137}Cs . Four additional columns were eluted at 0.64 column volumes/hr and one at 3 column volumes/hr to determine the effect of elution rate on cesium elution.

It should be noted that scrub sampling was instantaneous; i.e., since the column flow rate was known, 10 ml samples were collected at the time interval corresponding to each column volume. With the elutions, on the other hand, the whole column volume was collected each time. By mixing the 10 column volumes after individual sampling to obtain a composite sample, a composite sodium and cesium content could be determined.

After completing the design shown in Figure 1, cesium C/C_0 values (cesium effluent concentration/cesium influent concentration) were chosen at the same column volume values for the eight scrub cesium loss curves and these data were subjected to a Yates⁽²⁾ analysis. Effect totals were then tested at the 5% significance level.

AW500 columns were reused after elution by first washing with 2 column volumes of 0.1M NaOH before reloading. This removed ammonium ions from the columns and rebased them with sodium. This procedure was followed to avoid possible precipitation of aluminosilicates or aluminum compounds in the columns.

Davison 700 is a zeolite very similar in mineral structure to AW500. Comparative cesium loading curves were obtained for Davison 700 and AW500 zeolites.

RESULTS

The factorial design of Figure 1 was completed. Long and short AW500 columns, which were downflow loaded with synthetic PSN, were downflow scrubbed with 10 column volumes of 0.2M $(\text{NH}_4)_2\text{CO}_3$ at 1.5 column volumes/hr (results given in Figure 2). The sodium and cesium removal curves show that cesium losses are relatively low when the bulk of the sodium is replaced by ammonium. Somewhat greater cesium losses were experienced by the shorter AW500 column, a pattern that was repeated throughout the study. Another scrub experiment at 0.75 column volumes/hr with 35 and 50 cm AW500 columns was completed as shown in Figure 3. Little difference is apparent between Figures 2 and 3 except possibly the somewhat greater gap between long and short column cesium losses.

AW500 columns loaded with synthetic PSS to 75 column volumes were scrubbed at 1.5 column volumes/hr; the results are shown in Figure 4. Except for a belated upturn in the cesium loss curve for the shorter column, cesium losses are not substantially different from those shown in Figure 3. Another scrub of 35 and 50 cm AW500, synthetic PSS-loaded columns at 0.75 column volumes/hr gave the results shown in Figure 5. Once again, the cesium loss curves of the 35 and 50 cm columns are more widely separated. Closer examination, however, shows that the 50 cm column loss curve is lower than normal, and the 35 cm column loss curve is steeper than normal. It was therefore necessary to resort to a quantitative treatment and comparison of the cesium loss data to decide whether or not column length, or some other factor shown in Figure 1, was statistically significant. To make a statistical analysis of the data, it was necessary to choose a dependent variable that would be comparable for all eight experiments. This was done by using the C/C_0 values on the cesium loss curves at the same column throughput

FIGURE 2. Sodium Removal and Cesium Loss Curves Obtained During Downflow Column Scrubbing Operations. In 10 column volumes of scrub solution, the 50 cm column lost 0.73% of its original cesium load and 97.96% of its original sodium. Comparable values for the 35 cm column were 0.83% for cesium and 97.83% for sodium.

Columns - S = 35 cm x 3.8 cm diam, 20 to 50 mesh, AW500

L = 50 cm x 3.8 cm diam, 20 to 50 mesh, AW500

Flow Rate - 1.5 column volumes/hr

Temperature - 23 °C

Scrub Solution - 0.2M (NH₄)₂CO₃

Original Loading - 40 column volumes of synthetic PSN

FIGURE 3. Sodium Removal and Cesium Loss Curves Obtained During Downflow Column Scrubbing Operations. In 10 column volumes of scrub solution, the 50 cm column lost 0.77% of its original cesium load and 96.37% of its original sodium. Comparable values for the 35 cm column were 0.94% for cesium and 97.01% for sodium.

Columns - S = 35 cm x 3.8 cm diam, 20 to 50 mesh, AW500

L = 50 cm x 3.8 cm diam, 20 to 50 mesh, AW500

Flow Rate - 0.75 column volumes/hr

Temperature - 23 °C

Scrub Solution - 0.2M (NH₄)₂CO₃

Original Loading - 40 column volumes of synthetic PSN

FIGURE 4. Sodium Removal and Cesium Loss Curves Obtained During Downflow Column Scrubbing Operations. In 10 column volumes of scrub solution, the 50 cm column lost 0.34% of its original cesium and 97.20% of its original sodium. Comparable values for the 35 cm column were 0.70% for cesium and 97.21% for sodium.

Columns - S = 35 cm x 3.8 cm diam, 20 to 50 mesh, AW500

L = 50 cm x 3.8 cm diam, 20 to 50 mesh, AW500

Flow Rate - 1.5 column volumes/hr

Temperature - 23 °C

Scrub Solution - 0.2M (NH₄)₂CO₃

Original Loading - 75 column volumes of synthetic PSS

FIGURE 5. Sodium Removal and Cesium Loss Curves Obtained During Downflow Column Scrubbing Operations. In 10 column volumes of scrub solution, the 50 cm column lost 0.31% of its original cesium load and 97.08% of its original sodium. Comparable values for the 35 cm column were 1.49% for the cesium and 96.84% for the sodium.

Columns - S = 35 cm x 3.8 cm diam, 20 to 50 mesh, AW500

L = 50 cm x 3.8 cm diam, 20 to 50 mesh, AW500

Flow Rate - 0.75 column volumes/hr

Temperature - 23 °C

Scrub Solution - 0.2M (NH₄)₂CO₃

Original Loading - 64 column volumes of synthetic PSS

volume as the dependent variable. Assuming that there is interest in removing a maximum of sodium with minimal cesium loss, a column throughput value of 6 was chosen. At 6 column volumes, cesium losses were still low, while the bulk of the sodium had been removed. A statistical analysis of cesium loss values at 6 column volumes is given in Table II.

TABLE II. Statistical Analysis of Cesium Scrub Loss at 6 Column Volumes

Experiment No. in Figure 1	Cesium C/C ₀ Values	Effect Totals	Main Effect Identification
1	0.068	0.455	Grand Total
2	0.092	0.009	Na/Cs Loading Ratio
3	0.044	-0.097	Column Length
4	0.043	-0.043	
5	0.057	-0.039	Column Flow Rate
6	0.059	-0.037	
7	0.054	0.049	
8	0.038	0.007	

$$\sigma = \pm 0.0134, \sigma_{\text{Effect Total}} = (\sqrt{8})(\pm 0.0134) = \pm 0.0379$$

$$t \text{ at } 0.05 \text{ level} = 2.776$$

An effect total is significant if it exceeds ± 0.105 .

Note that none of the main effects is statistically significant at the usual 0.05 level. Therefore, as long as the columns are operated within the stated ranges of flow rate, sodium-to-cesium ratio and column length, cesium C/C₀ values at 6 column volumes of 0.2M (NH₄)₂CO₃ solution throughput will not vary significantly.

Sodium removal curves shown in Figures 2, 3, 4, and 5, on the other hand, show that the long column curves always preceded the short column curves, but were otherwise very similar. The physical condition of the columns is probably responsible for this behavior. Less freeboard between the

AW500 bed and top of the column for the long column usually meant that less of the washwater following the loading solution was present on the column to dilute the incoming scrub solution. Both glass columns were 3.8 cm diam and the same length (60 cm). Attempts were made to keep the height of liquid on top of both columns about the same, but usually the longer column top showed less liquid height.

The basic scrub data of Figures 2, 3, 4, and 5 are presented in a modified form in Figures 6, 7, 8, and 9. Both the sodium-to-cesium ratio of the sodium and cesium on the column and the instantaneous sodium-to-cesium ratio of the effluent leaving the column are plotted versus the column volumes of scrub solution throughput. By continuously measuring the sodium-to-cesium ratio of an operating column, and using the above data in Figures 6, 7, 8, and 9, the operator can determine optimum scrubbing volume to attain a given sodium-to-cesium ratio in the column elution step. It would appear from the data of Figures 6 and 7 for PSN-loaded columns that 5 column volumes of scrub solution is sufficient to attain sodium-to-cesium ratios of less than 10. Probably 6 column volumes of scrub solution should be used for columns loaded with PSS to attain the same sodium-to-cesium ratio of less than 10.

After the downflow loading and scrubbing processes, the columns were eluted downflow with 55 °C $2.0M$ NH_4OH + $3.0M$ $(NH_4)_2CO_3$ solution at various flow rates. Forty column volumes of synthetic PSN solution were loaded on the two AW500 columns which were then scrubbed and eluted as shown in Figure 10. The process was repeated and the results are shown in Figure 11. Variations of the curve positions can be expected for several reasons including localized column temperature differences and the amount of scrub solution on

FIGURE 6. A Plot of Sodium-to-Cesium Molar Ratios Versus Column Volumes of $0.2M (NH_4)_2CO_3$ Scrub for AW500 Columns Loaded with Synthetic PSN. Data are derived from Figure 2.

FIGURE 7. A Plot of Sodium-to-Cesium Molar Ratios Versus Column Volumes of $0.2M (NH_4)_2CO_3$ Scrub for AW500 Columns Loaded with Synthetic PSN. Data are derived from Figure 3.

FIGURE 8. A Plot of Sodium-to-Cesium Molar Ratios Versus Column Volumes of $0.2M (NH_4)_2CO_3$ Scrub for AW500 Columns Loaded with Synthetic PSS. Data are derived from Figure 4.

FIGURE 9. A Plot of Sodium-to-Cesium Molar Ratios Versus Column Volumes of $0.2M (NH_4)_2CO_3$ Scrub for AW500 Columns Loaded with Synthetic PSS. Data are derived from Figure 5.

FIGURE 10. Downflow Cesium Removal Curves from Downflow PSN-Loaded, Downflow Scrubbed Columns During Elution.

Columns - S = 35 cm x 3.8 cm diam, 20 to 50 mesh, AW500

L = 50 cm x 3.8 cm diam, 20 to 50 mesh, AW500

Flow Rate - 0.64 column volumes/hr

Temperature - 55 °C

Eluting Solution - 2.0M NH_4OH + 3.0M $(\text{NH}_4)_2\text{CO}_3$

Original Loading - 39 column volumes of synthetic PSN

Elution - S = 35.9 column volumes recovered

L = 38.7 column volumes recovered

FIGURE 11. Downflow Cesium Removal Curves from Downflow PSN-Loaded, Downflow Scrubbed Columns During Elution.

Columns - S = 35 cm x 3.8 cm diam, 20 to 50 mesh, AW500
 L = 50 cm x 3.8 cm diam, 20 to 50 mesh, AW500

Flow Rate - 0.64 column volumes/hr
 Temperature - 55 °C
 Eluting Solution - 2.0M NH₄OH + 3.0M (NH₄)₂CO₃
 Original Loading - 39 column volumes of synthetic PSN

Elution - S = 47.6 column volumes recovered (?)
 L = 39.1 column volumes recovered

top of the column at elution commencement. The cause of occasional elution curve asymmetry is not known. The bulk of the adsorbed cesium was apparently removed by 12 column volumes of eluting solution at 55 °C.

The columns were reloaded with 40 column volumes of PSN after an initial wash with 0.1M NaOH, scrubbed and eluted twice at flow rates of 1.5 and 0.75 column volumes/hr. The results are given in Figures 12 and 13. In these instances, all four of the cesium elution curves are nearly coincidental and similar to the curves of Figures 10 and 11 despite the faster column flow rate. Twelve column volumes were still sufficient to remove most of the adsorbed cesium.

The two columns were then loaded with 75 column volumes of synthetic PSS (3.79N Na) containing considerably less sodium than PSN (5.14N Na), scrubbed and eluted at 1.5 column volumes/hr; the results are shown in Figure 14. Although the cesium C/C_0 values attained during elution were higher, the elution also was finished at about 12 column volumes. Again, the column length had little effect on the shape of the elution curve. A rerun of Figure 14 with 65 column volumes of PSS solution produced the elution curves shown in Figure 15. The curve differences are normal and the elution is finished at the same 12 column volumes.

Since elution flow rate did not seem to have an appreciable effect on the shape of the elution curve to 1.5 column volumes/hr, a 35 cm column was loaded with 64 column volumes of PSN, scrubbed and eluted at 3.0 column volumes/hr. The results, as seen in Figure 16, are a nearly normal elution curve. A closer inspection, however, indicates that a "tail" is beginning to develop due to disequilibrium between eluting solution ammonium cations and adsorbed cesium cations. It is suggested that elution flow rates be held to values less than 3.0 column volumes/hr, if possible.

FIGURE 12. Downflow Cesium Removal Curves from Downflow PSN-Loaded, Downflow Scrubbed Columns During Elution.

Columns - S = 35 cm x 3.8 cm diam, 20 to 50 mesh, AW500
 L = 50 cm x 3.8 cm diam, 20 to 50 mesh, AW500

Flow Rate - 1.5 column volumes/hr
 Temperature - 55 °C
 Eluting Solution - 2.0M NH₄OH + 3.0M (NH₄)₂CO₃
 Original Loading - 40 column volumes of synthetic PSN

Elution - S = 43.1 column volumes recovered
 L = 40.4 column volumes recovered

FIGURE 13. Downflow Cesium Removal Curves from Downflow PSN-Loaded, Downflow Scrubbed Columns During Elution.
Columns - S = 35 cm x 3.8 cm diam, 20 to 50 mesh, AW500
L = 50 cm x 3.8 cm diam, 20 to 50 mesh, AW500
Flow Rate - 0.75 column volumes/hr
Temperature - 55 °C
Eluting Solution - 2.0M NH₄OH + 3.0M (NH₄)₂CO₃
Original Loading - 40 column volumes of synthetic PSN
Elution - S = 40.7 column volumes recovered
L = 42.3 column volumes recovered

FIGURE 14. Downflow Cesium Removal Curves from Downflow PSS-Loaded, Downflow Scrubbed Columns During Elution.
Columns - S = 35 cm x 3.8 cm diam, 20 to 50 mesh, AW500
L = 50 cm x 3.8 cm diam, 20 to 50 mesh, AW500
Flow Rate - 1.5 column volumes/hr
Temperature - 55 °C
Eluting Solution - 2.0M NH₄OH + 3.0M (NH₄)₂CO₃
Elution - S = 75.0 column volumes recovered
L = 76.7 column volumes recovered

FIGURE 15. Downflow Cesium Removal Curves from Downflow PSS-Loaded, Downflow Scrubbed Columns During Elution.
Columns - S = 35 cm x 3.8 cm diam, 20 to 50 mesh, AW500
L = 50 cm x 3.8 cm diam, 20 to 50 mesh, AW500
Flow Rate - 0.75 column volumes/hr
Temperature - 55 °C
Eluting Solution - 2.0M NH₄OH + 3.0M (NH₄)₂CO₃
Original Loading - 65 column volumes of synthetic PSS
Elution - S = 63.8 column volumes recovered
L = 66.3 column volumes recovered

FIGURE 16. Downflow Cesium Removal Curve from a Downflow PSN-Loaded, Downflow Scrubbed Column During Elution.
Column - 35 cm x 3.8 cm diam, 20 to 50 mesh,
AW500
Flow Rate - 3.0 column volumes/hr
Temperature - 55 °C
Eluting Solution - 2.0M NH_4OH + 3.0M $(\text{NH}_4)_2\text{CO}_3$
Original Loading - 64 column volumes of synthetic
PSN
Elution - 64.0 column volumes recovered

As can be seen from the data on column volumes loaded and column volumes eluted in Figures 10 through 16, cesium material balances are in error from 2 to 5%, but tend to support the view that elution was nearly completed. No evidence for a continued cesium buildup on the columns was noted after 8 to 10 loading cycles.

After individual sampling and plotting of sodium and cesium removal data as shown in Figures 12, 13, 14, and 15, the column volume samples were composited and sodium and cesium content determined from the composite sample. The sodium-to-cesium ratios of the composites are given in Table III.

TABLE III. Sodium-to-Cesium Molar Ratios in the Combined Eluates for Composite Samples of Columns Shown in Figures 12 Through 15.

<u>Figure Number</u>	<u>Column</u>	<u>Na, mg</u>	<u>Cs, mg</u>	<u>MNa/MCs</u>
12	long	290	2428	0.71
12	short	216	1698	0.76
13	long	516	2428	1.27
13	short	298	1698	1.05
14	long	248	400	2.95
14	short	188	350	3.20
15	long	425	434	5.83
15	short	323	304	6.33

The above values correspond with sodium-to-cesium ratios on the column at 10 column volumes given in Figures 6, 7, 8, and 9.

Another chabazite-like zeolite, Davison 700, was compared to the cesium removal performance of AW500; the results are shown in Figure 17. Note the irregularity of the 700 cesium removal curve as compared to the AW500 removal curve. The dashed portions of the 700 curve represent overnight (16 hr) shutoff and recovery of the column, an obvious indicator of

disequilibrium or poor exchange kinetics between solution and zeolite adsorbed cations. To efficiently utilize the 700, it must either be reduced in grain size from its present 8 to 12 mesh or the column flow rate could be reduced. The AW500 column (20 to 50 mesh) also was shut down at the same times as the 700 column, but being at equilibrium, there was no appreciable change in AW500 cesium removal upon standing overnight. To show how poor exchange kinetics would effect normal scrub and elution cycles as well, an 8 to 12 mesh 700 column was loaded with 40 column volumes of synthetic PSN and scrubbed with $0.2M (NH_4)_2CO_3$ solution. The results are shown in Figure 18. The sodium removal curve "tails" badly and cesium losses are relatively high. Cesium elution from the 700 column is given in Figure 19. This curve shows a relatively low cesium elution rate, related once again to poor exchange kinetics. Further study on 20 to 50 mesh 700 would be required for a valid comparison with AW500.

The effect of elution volume on cesium breakthrough on the subsequent loading cycle is illustrated in Figures 20, 21, and 22. These experiments were conducted with 60 cm^3 columns of AW500 and a simulated alkaline supernatant waste, Purex 'A', which contained 4.4 moles/liter Na^+ and 7.6×10^{-4} moles/liter Cs^+ . The loaded columns were scrubbed with 8 column volumes of $0.2M (NH_4)_2CO_3$ prior to elution with $2M NH_4OH + 3M (NH_4)_2CO_3$ at $55^\circ C$ and were washed with 3 column volumes of water after elution. The total cesium waste loss during the loading cycle after 8, 16, and 24 column volumes of eluting solution was 2.2, 0.068, and 0.017%, respectively. By comparison, cesium waste losses with the 35 and 50 cm columns and simulated PSN varied between 0.1 and 1.0% after 16 column volumes of $2M NH_4OH + 3M (NH_4)_2CO_3$ at $55^\circ C$. The difference between the PSN and

FIGURE 17. Comparative Cesium Loading Curves for Davison 700 and AW500 Zeolites.

Columns - 35 cm x 3.8 cm diam, 20 to 50 mesh,
AW500

35 cm x 3.8 cm diam, 8 to 12 mesh, 700

Flow Rate - 1.5 column volumes/hr

Temperature - 23 °C

Loading Solution - synthetic PSN

FIGURE 18. Sodium Removal and Cesium Loss Curves Obtained During Downflow PSN-loaded Column Scrubbing Operations.

Column - 35 cm x 3.8 cm diam, 8 to 12 mesh, 700

Flow Rate - 1.5 column volumes/hr

Temperature - 23 °C

Scrub Solution - 0.2M $(NH_4)_2CO_3$

Original Loading - 40 column volumes of synthetic PSN

FIGURE 19. Downflow Cesium Removal Curve from a Downflow PSN-loaded, Downflow Scrubbed During Elution.

Column - 35 cm x 3.8 cm diam, 8 to 12 mesh, 700

Flow Rate - 1.5 column volumes/hr

Temperature - 55 °C

Eluting Solution - 2.0M NH_4OH + 3.0M $(\text{NH}_4)_2\text{CO}_3$

Original Loading - 40 column volumes of synthetic
PSN

Elution - 19.1 column volumes recovered

FIGURE 20. Cesium Breakthrough Following 8 Column Volumes of Eluting Solution

FIGURE 21. Cesium Breakthrough Following 16 Column Volumes of Eluting Solution

FIGURE 22. Cesium Breakthrough Following 24 Column Volumes of Eluting Solution

Purex 'A' data is believed due to the higher cesium loading possible with Purex 'A' supernatant and a possible higher exchange capacity with the different batch of AW500 used in the Purex 'A' experiments.

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