

THE DECONTAMINATION OF SPENT REGENERANT BY ION EXCHANGE AND FILTRATION

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ABSTRACT

The sodium sulfate solutions produced by the regeneration of deep bed polisher resins have typically been prepared for disposal by concentration by evaporation followed by solidification in concrete. Filtration and ion exchange followed by discharge of the sodium sulfate solution is one possible alternative to evaporation and solidification. The high salt content of the solutions makes the use of non-selective ion exchange resins volume inefficient. This paper describes tests using filtration and selective ion exchange to clean regenerative wastes. It concludes that such a process is technically feasible and would result in substantial cost savings and volume reduction.

INTRODUCTION

The regeneration of deep bed polisher resins has lost favor at United States' utilities. One reason has been the cost and difficulty of handling the regenerate wastes. The sodium sulfate solutions produced are typically concentrated by evaporation and solidified in concrete. The cost of this process is such that it has been deemed more economical to simply dispose of the spent resins. One alternative method of processing is the use of ion exchange of the solution followed by the dewatering of the ion exchange media and disposal in a high integrity container (HIC). The high salt concentration (0.1-2%) makes the use of non-selective ion exchange media volume inefficient. However, there exist ion selective media that allow the major ionic components of the regenerate solutions (Na^+ , SO_4^-) to pass through while the radioactive ions are removed. The use of filtration plus selective ion exchange should provide a low cost and volume efficient alternative to evaporation and solidification.

A shipment of regenerate waste water samples from a Midwestern nuclear plant was received at the Vitreous State Laboratory at the Catholic University of America on July 15, 1986. The shipment contained four samples totaling four liters of water which were clear with brown and black precipitated particles.

ANALYSIS

The four samples were combined and analyzed for radioactive and non-radioactive species. The results of these analyses are given in Table I. The water was slightly acidic with a pH of 6.6 and had a high conductivity (2,900 μS). The major non-radioactive species of interest were sodium (662 ppm) and sulfate (1,470 ppm). It is these species that will compete for ion exchange sites with the

radioactive species such as cesium, cobalt and manganese. The major radioactive species of interest were Mn-54, Co-58/60 and Cs 134/137. The latter, although low in concentration, would be the major contributor to offsite dose.

TABLE I

Chemical & Isotopic Analysis of Regenerate Water

pH		6.6
Conductivity (μS)		2900
		<u>ppm</u>
Na		662
Si		1.3
K		1.3
Mg		1.0
Ca		0.9
Fe		0.4
Mn		0.1
Zr		0.1
NH_3		4.0
SO_4		1470
	<u>Bq/ml</u>	<u>($\mu\text{Ci/ml}$)</u>
Cs 134	1.4	(3.9E-05)
Cs 137	2.4	(6.6E-05)
Co 58	10	(2.7E-04)
Co 60	85	(2.3E-03)
Cr 51	10	(2.8E-04)
Mn 54	74	(2.0E-03)
Fe 59	3.0	(8.2E-05)
Sb 124	0.1	(3.2E-06)
Zn 65	3.7	(1.0E-04)

TESTING

Filtration tests: The water was filtered through a series of graduated filters; the results are tabulated in Table II.

Column tests: The water was filtered through a 5 u filter and then passed through test columns filled with one ml of ion exchange media. This small column volume is dictated by the limited amount of water available. Previous experience at this laboratory has confirmed that such columns give a very accurate estimate of the ion exchange capacity

TABLE II

Filtration Test Results

Filter Size (micron)	Decontamination Factors		
	Cs 134/137	Co 58/Mn 54	Co 60
20.0	1.2	2.3	3.5
5.0		2.3	3.7
0.45	1.6	2.4	3.9
0.22	1.4	2.4	4.1

that will be obtained in full scale plant systems. The decontamination factor (DF = influent activity/ effluent activity) obtained in small column testing are often exceeded by a factor 2-5 in full scale systems. The laboratory tests, thus, give a conservative picture of in-plant performance.

In order to establish a baseline for performance, organic ion exchange columns were tested first. The organic test column consisted of a 50/50 layered bed of strong acid cation resin and strong base anion resin. The layered bed arrangement is typical of the organic resin combination used in most nuclear power plants. A column containing Durasil[®] 10 media and Durasil[®] 70 (manufactured by Duratek Corporation) was then run. This combination of ion selective media is designed for maximum removal of radioactive cesium, cobalt and manganese.

The results of the column tests are given in Tables III and IV which give DF value versus throughput in m^3/m^3 (gal/ft^3). The minor fluctuations in DF seen in the tables are due to the small sample volumes (25 ml) used in counting and the low levels of radioactivity in the effluent. The small count volumes are necessary due to the small column size.

TABLE III

Column Test Results Organic Resins

Sample	Throughput m^3/m^3 (gal/ft^3)	Decontamination Factors		
		Cs 134/137	Co 58/Mn 54	Co 60
1	13 (95)	28.3	51.1	51.9
2	38 (288)	5.5	35.9	33.6

RESULTS AND DISCUSSION

The filtration results show that a standard 20 u filter would be effective for processing the regenerate water. Very little, if anything, is gained by using finer filters down to 0.22 u. As expected, those isotopes that have a tendency to form particulates such as Co 58/60 and Mn 54 have a greater DF across the filter. Approximately 60% of the Co 58/Mn 54 and 75% of the Co 60 are stopped by the filters. The Cs isotopes are generally not found in particulate form in most waste streams. The fact that ~30% of the Cs was stopped by the filters leads us to suspect that some resin fines are present in the water. Such an occurrence would not be un-

TABLE IV

Column Test Results Selective Ion Exchange Media

Sample	Throughput m^3/m^3 (gal/ft^3)	Decontamination Factors		
		Cs 134/137	Co 58/Mn 54	Co 60
1	13 (94)	>20	>1000	>1000
2	38 (285)	>20	607.0	>1000
3	63 (472)	>20	749.0	>1000
4	97 (730)	>20	552.0	>1000
5	131 (981)	>20	>1000	>1000
6	173 (1296)	>20	396.0	298.0
7	217 (1625)	>20	65.0	49.0
8	271 (2030)	9.6	15.0	41.0
9	353 (2644)	14.6	17.0	32.0
10	419 (3146)	16.2	17.0	28.0
11	474 (3558)	16.4	11.0	21.0
12	530 (3975)	6.9	6.7	22.0

expected in regenerate wastes. The column test results may be summarized as follows:

1. The organic resins are exhausted (DF >10) at approximately 27 m³/m³ (200 gal/ft³).
2. The Durasil® media were exhausted after 480 m³/m³ (3,600 gal/ft³).
3. The DFs for all species were sufficient to produce effluent concentrations which would be acceptable for release to the environment. For example, DFs of 20 for Cs 134/137, 500 for Co 58/Mn 54 and 1,000 for Co 60 would produce an effluent that is 0.19 Bq/ml (5E-6 uCi/ml) for Cs 134/137, 0.02 Bq/ml (5.4E-7 uCi/ml) for Co 58, 0.15 Bq/ml (4E-6 uCi/ml) for Mn 54 and 0.085 Bq/ml (2.3E-6 uCi/ml) for Co 60.

The impact of the above results on volume reduction (VR) for radwaste treatment can be estimated based on the assumptions and calculations given in Appendix A. The results are given in Table V.

CONCLUSION

The use of selective ion exchange media to process regenerate wastes is shown to be technically feasible and results in substantial savings in volume of waste, costs and personnel exposure. The effluent water would be releasable in terms of radioisotope levels. It must be pointed out that the water tested contained approximately 2,000 ppm of Na₂SO₄ which would be present in the effluent. Release of this level of total dissolved solids would depend on permitting which would be site specific. Ocean plants should have

TABLE V

Volume Reduction Factors for the Treatment of Regenerate Wastes

Method	VR	Burial Volume/Yr m ³	(ft ³)	HICs/Yr
Organic Resin	26.7	142	(5,000)	31
Evaporation	65.0	58	(2,054)	13
Selective Media	480	8	(278)	<2

little difficulty in this regard while fresh water sites would have to be evaluated on an individual basis.

APPENDIX A

Calculation of Volume Reduction Factors

I. Ion Exchange

$$VR = \frac{\text{throughput in m}^3/\text{m}^3}{\frac{\text{throughput in gal/ft}^3}{7.49 \text{ gal/ft}^3}}$$

II. Evaporation

Assume:

- i. solids are concentrated to 20% (200,000 ppm)
- ii. solidification efficiency is 0.70 (70%)

$$VR = \frac{(200,000 \text{ ppm})}{(\text{ppm total dissolved solids})} (\text{solidification efficiency})$$

III. Volume Buried/Year

Assume:

28,300 m³ (1,000,000 gal) of water processed

$$V = \frac{28,300 \text{ m}^3}{VR} = \frac{1,000,000 \text{ gal}}{7.49 \text{ gal/ft}^3} \cdot VR$$

IV. HICs Buried/Year

Assume:

internal volume of the HIC is 4.5 m³ (161 ft³)

$$HICs/yr = V/4.5 = (V/161 \text{ft}^3)$$