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BHABHA ATOMIC RESEARCH CENTRE

APPLICATION OF BIOMASS FOR THE SORPTION OF
RADIONUCLIDES FROM LOW LEVEL PUREX AQUEOUS WASTES

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60 Abstract : Microbial biomass have been found to be good biological adsorbants for radioactive nuclides such as uranium and thorium with comparatively easy desorption and recovery. Based on this, sorption studies have been carried out to assess the feasibility of using biomass *Rhizopus arrhizus* (RA) for the removal of radionuclides present in Purex low level waste streams. Biomass *Rhizopus arrhizus* (RA) appears effective for the removal of actinides and fission products from low level Purex plant waste/effluent solutions. Maximum sorption for uranium and plutonium is observed at 6-7 pH whereas for Am, Eu, Pm, Ce and Zr the sorption is maximum at pH 2 with high D values and fast kinetics in both cases. Sorption for Ru and Cs are negligible. Sorbed nuclides are recoverable by elution with 1 M HNO₃, on once through basis. The method can be used for treating the evaporator condensates from the plant and the hold-up delay tank solution. The sodium nitrate salt concentration in the aqueous solution beyond 0.14 M seriously affects the metal uptake. The results from column experiments indicate a limited loading capacity in terms of mg of Am/U/Pu etc. per gm of RA. However, as the Purex low level effluents contain only trace level activities whose absolute ionic concentrations are much lower, the capacities observed with the present form of biomass may still be satisfactory.

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1. INTRODUCTION

Increasing awareness of the environmental impact of heavy metal radioactive pollutants from Nuclear Industries on aqueous systems has led to a keen interest in studies on novel adsorption systems for such metal ions. Both organic and inorganic cation exchangers are employed for sorption of metal ions. Considerable research has been carried out recently, with materials of biological origin, and many forms of biomass have shown good metal sorption(1,2,3). Selected types of microbial biomass have been shown to act as very good biological adsorbants for radioactive nuclides such as uranium and thorium with comparatively easy desorption and recovery. Despite the extensive literature available on metal biomass interactions, little information on the applications of biosorption in nuclear waste management is reported.

Uranium adsorption by the biomass, Rhizopus arrhizus (RA) in particular, has been investigated extensively and the adsorption equilibrium, kinetics and mechanistic aspects of the process have been reported in detail(4). This biomass readily sorbs uranium which is recoverable. Various eluents which have been used for the elution of uranium from the biomass are ammonium sulphate, sodium carbonate, sodium bicarbonate and the three mineral acids, HNO₃, HCl and H₂SO₄ (5). Sodium bicarbonate appears to be promising and efficient as it causes minimum damage to the

biomass ensuring its reusability. On the contrary, the mineral acids, though very good eluting agents, cause damage to the biomass.

The present work pertains to the basic studies on the feasibility of the use of Rhizopus arrhizus (RA), a biosorbant, for the treatment of low level radioactive wastes before their final disposal to the environment. The biosorbant has been compared with Dowex 50X4 in H^+ and $N_2H_5^+$ forms as well as with ammonium molybdophosphate with respect to sorption of a few radionuclides. The distribution ratios for a few alpha emitting nuclides (^{233}U , ^{239}Pu and ^{241}Am) and for some of the fission products ($^{152,154}Eu$, ^{147}Pm , ^{144}Ce , ^{106}Ru , ^{95}Zr , ^{137}Cs , ..etc.) on the biosorbant have been determined. The biosorbant has also been tested with actual Purex low level waste.

2. EXPERIMENTAL

2.1 Reagents and Chemicals

The radioactive tracers ^{233}U , Pu (mainly 239), ^{241}Am , $^{152,154}Eu$, ^{95}Zr , ^{147}Pm and ^{144}Ce were procured and purified by standard procedures(6,7,8) and assayed either with a well type gamma scintillation counter using a $NaI(Tl)$ detector or with proportional counters using argon or burshane gas depending on the nature of their activities. Individual fission products were determined by gamma spectrometry using a HPGe detector coupled to a 4K multichannel analyser.

The fungus Rhizopus arrhizus (RA), Gibberella Fuiikuroi NCIM 665 A-1 and A-2 and Gibberella Saubinetti NCIM 851 were obtained from National Collection of Industrial Microorganisms (NCIM), National Chemical Laboratory, Pune. The culture was propagated in PDA slants having the following composition potato extract 20%, dextrose 2%, and agar 3% w/v and the pH adjusted to 5.8. The fungus from PDA slants was cultivated on 150 ml sterilized modified Czepak Dox medium (9,10) in 500 ml erienmeyer flask at

room temperature on a rotary shaker at 150 r.p.m. The substrate aromatic ketones (100 mg/ml in 95% alcohol) were added to a 72 hrs. grown culture and incubated at room temperature on a rotary shaker for two weeks (11,12). At the end of fermentation the mycelial mass was filtered from the culture medium, washed 3 times using about 50 ml of acetone and air dried. Micelia (biomass) was further dried at 110°C to constant weight. The product was ground using a mortar and pestle and sieved into various mesh sizes.

Dowex 50X4 (100-200 mesh size) in H^+ form, supplied by Dow Chemical Company, USA was used after conditioning with 1 M HNO_3 , and after converting to $N_2H_5^+$ form by passing 0.13 M N_2H_4 at 0.09 M HNO_3 . Ammonium molybdophosphate (AMP), AG from Biorad was used as such. All other chemicals used were of AR/LR grade.

2.2 Comparative Study of Different Sorbants

In order to compare the sorption behaviours of different sorbants, 5.0 ml of very low level aqueous waste (waste evaporator condensate) from Purex plant was spiked with high level waste for increasing the beta and gamma activity levels and contacted with about 100 mg each of Dowex 50X4 resin (both H^+ and $N_2H_5^+$ forms), ammonium molybdophosphate (AMP) and biomass RA for 30 min. and the fission product activities in the feed as well as effluent were determined.

2.3 Stability of Rhizopus Arrhizus

The stability of biomass RA was assessed by treating about 500 mg of the material with 50 ml of HNO_3 (2, 4 & 8 M), NaOH (2 & 4 M) and 30 % TBP-dodecane for about 24 hours and the characteristics of the treated materials and the leach liquors, and the physical damage caused to RA were assessed.

RA was boiled with distilled water for 30 min. and its physical characteristics were also observed.

2.4 Batch Equilibrium Studies with Various Radioactive Nuclides

In all the batch extraction studies, a known volume (generally 2 ml) of the aqueous phase containing radioactive tracer was equilibrated with biomass of known weight (generally 10-30 mg). All pH adjustments were done either with HNO₃ or Na₂CO₃. The equilibration was done using a mechanical shaker. After the equilibrium was attained, the effluents were filtered and assayed for their activity. The distribution ratios were calculated using the formula,

$$D = \frac{(A_i - A_f) \quad V}{A_f \quad M}$$

where, A_i and A_f are the activities of the tracers in initial and final solutions respectively, V is the volume of the solution in ml and M is the weight of the biomass in gm.

To compare the performance of different types of biomass, about 30 mg each of four types of biomass (Rhizopus arrhizus (RA), Gibberella Fuiikuroi NCIM 665 A-1, Gibberella Fuiikoro NCIM 665 A-2 and Gibberella Saubinetti NCIM 851) were individually contacted with Pu solution at tracer level in acidic as well as alkaline medium (pH 4 and 9) and the distribution ratios for Pu were determined. With biomass RA, D_{Am} was determined as a function of contact time to arrive at optimum equilibration time.

Using RA, D values were determined for U, Pu, Am, Eu, Pm, Ce and Zr at pH varying from 2 to 11. D_{Pu} were determined at 0.1 M concentration of SO₄²⁻, C₂O₄²⁻, NO₃⁻, CH₃COO⁻, Cl⁻ and CO₃²⁻ at pH 4. D_{Am} were determined at varying concentrations of NaNO₃ and Nd(III) at pH 2.

2.5 Column Experiments

Column experiments were carried out to assess the break-through capacity of RA. A solution of 350 mg/l Nd(III) with ^{241}Am as tracer at pH 2 was passed through a column of 1.002 g of RA at a flow rate of 2 BV/Hr. Effluents were collected in lots of 5 ml. After attaining 100% BT, the column was washed with dilute HNO_3 (pH 2) till activities reached background level. The column was eluted with 1 M HNO_3 till the elution product activities reached background level. The entire product solutions were collected and estimated for Am activity.

A solution of 3.0 mg/l Pu adjusted to pH 9.4 with sodium carbonate solution was passed through another column containing 0.1007 g of biomass at a flow rate of 6 BV/Hr. till 100% breakthrough was attained. The effluents were collected in 5 ml lots. The column was washed with 9.4 pH solution till the activities reached background level. Plutonium from the column was recovered by elution with 1 M HNO_3 .

2.6 Experiments with Purex Plant Waste Streams

In order to assess the sorption characteristics of radionuclides of relevance to Purex process by RA, a small aliquot of Purex high level waste solution (HAW CON) was diluted to 5.0 ml at pH 2 and was contacted with about 100 mg of RA for 15 min. and the activities in the effluents were determined.

The loading effluent solution generated during the CMPO extraction chromatographic loading experiments(13,14) for partitioning of minor actinides from U depleted Purex high level waste (HLW) solution was diluted 50 times at pH 2. From this solution, 5.0 ml was contacted with about 100 mg of RA for 3 hrs. Gross alpha, beta, gamma and some of the individual fission product activities in the effluent were monitored.

Similarly, 20 ml of the 0.04 M HNO₃ eluent fraction from the above CMPO extraction chromatographic experiment, containing trivalent actinides and lanthanides was contacted, as such and after adjusting the pH to 2, with RA (200 mg) for 3 hrs. and the activities in the effluents were measured.

From the Purex low level waste Hold-up-cum-Delay Tank, 100 ml was contacted with 500 mg of RA for 3 hours. Same experiment with Am as tracer was repeated twice, once as such and the other after adjusting the pH to 2. The gross alpha activities in the feeds and effluents were analysed. The experiments were continued for 3 more hours and the effluents were again analysed to assess contact time requirements.

Similarly, 100 ml of evaporator condensate solution was spiked with plutonium and contacted with 100 mg of RA for 3 hrs. The experiment was repeated after adjusting the pH to 2 and 6, and the analyses were done as before.

3. RESULTS AND DISCUSSION

Basic studies have been carried out to assess the feasibility of using biosorbants for treating the low level radioactive wastes before their final disposal to the environment.

The mechanism of metal uptake by microorganism is quite complex. The actual uptake of the metal ions on the cellular surface may include physical adsorption, ion-exchange, chemisorption, etc. In this work, the term sorption is used to describe any of these possible interactions between the metal ions and the biomass without any distinction.

3.1 Efficacy of RA as a Sorbant for Radionuclides

The results of a comparative study of the sorption behaviours of sorbants, Dowex 50X4 resin (both H⁺ and N₂H₅⁺ forms), ammonium molybdophosphate (AMP) and Rhizopus arrhizus for sorption of

fission products ^{144}Ce , ^{125}Sb , ^{106}Ru and ^{137}Cs are presented in Table 1. Cation exchanger, Dowex 50X4, in both the forms, is the best sorbant for Ce with a D in the range 10^4 at 0.14 M HNO_3 as well as at pH 2, with very low sorption of other nuclides. AMP is a very good sorbant for Cs alone only at pH 2. In the case of biomass RA, Ce sorption is less compared to Dowex resins, but is still substantially high for large scale applications. The sorption of alpha emitters on biomass is also satisfactory as can be seen from the results presented in Table 2.

3.2 Choice of Biomass and Sorption Kinetics

Batch sorption data for plutonium at pH 4 and 9 on various biomass samples that have been used in the present studies are given in Table 2. From the Table, it is evident that Rhizopus arrhizus shows very high distribution ratio for Pu at pH 4 and 9 compared to other biomass samples used, and therefore further studies have been carried out with RA of 30-50 mesh size.

The kinetics of ^{241}Am sorption by RA at pH 2 is presented in Table 3. Am sorption occurs rapidly and because of high D values, more than 95% sorption takes place within 5 minutes of metal-biomass contact. Substantial increase in D_{Am} is observed within 15 min. Sorption continues on further contact, but at a very low rate, and the system takes about 3 hrs. to attain equilibrium. However 15 min. has been fixed as contact time in most of the batch experiments.

3.3 Stability of RA

In the experiments where RA was treated with acids, alkalies and TBP, the leach liquors of acids and alkalies show yellow and brown colouration respectively while that of TBP is colourless. TBP causes apparently no structural damage to the biomass while both acid and alkali treated ones become sticky in nature. RA after boiling with water for about 30 min. shows substantially reduced sorption characteristics.

3.4 Batch Sorption Studies of Radionuclides on RA

Uptake of actinides (U(VI), Pu(IV), Am(III)) and some fission products (trivalent Ce, Pm and Eu and also Zr) at varying pH (2-11) are presented in Table 4. Maximum D values were observed for U and Pu at 6-7 pH whereas for trivalent actinides and fission products, highest uptake was at pH 2. Data have not been collected at higher acidities (less than pH 2) as RA is not stable at these acidities. But the D values for Am were found to decrease below pH 2.

As it is well known that Pu has a tendency to hydrolyse at the pH regions under test, special efforts were made to ascertain the reproducibility of the results. Further, blank equilibration experiments with Pu in the acid pH regions (and in sodium carbonate solution at pH 9.4) under test in the absence of RA did not reveal any reduction in supernatant activity even after allowing the solution to stand for about 2 days. Other experiments also confirm that the reduction in activity observed on contact with RA was only due to sorption by RA. Further, the variation in sorption behaviour with pH was distinctly different for Pu and Am.

RA was contacted with plutonium solutions in presence of anions chloride, nitrate, sulphate, carbonate, oxalate and acetate individually at 0.1 M concentration at pH 4. $D_{Pu^{4+}}$ obtained are presented in Table 5. In all the cases the presence of anions have considerably reduced the D values for Pu, showing a minimum value in the case of oxalate. D_{Pu} with respect to the interfering ions is in the order $SO_4^{--} > Cl^- > CO_3^{--} > NO_3^- > CH_3COO^- > C_2O_4^{--}$.

The distribution ratios for Am in RA in presence of $NaNO_3$ upto 1.4 M are presented in Table 6. It is clear from the Table that the presence of salt above 0.14 M drastically reduces D_{Am} . It can reasonably be assumed that upto 0.14 M salt ($NaNO_3$), there is no significant effect on the uptake of Am.

To assess the impact of metal ion concentration on the uptake, distribution ratios of Am(III) was determined at varying Nd(III) concentration upto 2.0 g/l in 2.0 ml solution with 20 mg of RA as sorbant and the results are presented in Table 7. Here Nd was used as substitute for actinides/lanthanides. It is seen that the D value decreases drastically as the Nd(III) concentration is increased to 0.02 g/l and this trend continued.

3.5 Column Experiments

After establishing the feasibility of sorption of radionuclides on RA, further investigations were carried out in column experiments. Am sorption was studied using feed solution with 350 mg/l Nd(III) (in place of Am(III)) with ^{241}Am as tracer at pH 2. 20 ml of the feed could be passed through 1.002 g column without any breakthrough (BT) while 30 ml feed was sufficient for 100% break-through. The column was washed with pH 2 solution till the effluent activity reached background level. The effluents and washings were collected together and analysed for Am activity. The difference between the feed and effluent activities is the activity sorbed by RA of known weight and the sorption per g of RA, which is the capacity at 100% BT, is calculated. In the case of Nd at pH 2, the capacity was found to be about 8 mg/g of RA.

When 3 mg/l Pu solution at 9.4 pH was passed through 0.1 g biomass RA (column volume, 0.5 ml) at 2 BV/Hr, 16 ml of the feed could be passed without any break-through and 60 ml feed was needed for 100% BT. Elution with 2 M HNO_3 could quantitatively recover the sorbed Pu. Pu sorption capacity of RA was calculated as above and was found to be 807.57 $\mu\text{g/g}$ of RA at pH 9.4.

The present results indicate a limited capacity for RA. Literature data(15) suggest very high saturation capacities for biomass (especially for $\mu\text{g/g}$) under different experimental conditions with biomass prepared by different techniques. However, as the Purex low level effluents contain only trace

level activities whose absolute ionic concentrations are much lower, the capacities observed with RA may still be satisfactory.

A good material balance was observed in the column experiments. In all the present experiments, Pu was initially present as Pu(IV). (In few cases where it was possible, Pu estimation (by TTA extraction) of feed/supernatant/effluent revealed that Pu was mainly present as Pu(IV)). In this work, sorption characteristics of Pu(VI) and Pu(III) have not been reported. These studies are still in progress.

3.6 Sorption of Radionuclides Present in Purex Waste Streams

The sorption of activities present in different waste streams of Purex process was tested with RA. Table 8 presents the data on sorption of alpha, beta and gamma activities present in Purex high level waste (50 times diluted), at pH 2 by Rhizopus arrhizus. Besides Pu and Am, the waste matrix contained fission products, ^{144}Ce , ^{106}Ru , ^{137}Cs and ^{95}Zr . The Table shows more than 99% sorption for ^{144}Ce and ^{95}Zr whereas the sorption is negligible for ^{106}Ru and monovalent metal ions. The Table also shows only about 95% sorption of gross alpha and this can be explained as due to the presence of plutonium which unlike americium, has lower D value at pH 2 as shown in Table 4.

Table 9. presents the results obtained for the biomass sorption of gross β , γ , and fission products Ru and Cs from the effluent generated during the loading of uranium lean HLW on a CAC column (13,14). For the RA loading experiment, the effluent was diluted to 50 times and adjusted to pH 2 prior to equilibration. This solution did not contain any alpha activity. It is clear from the Table that the sorption of ^{106}Ru and ^{137}Cs are negligible. Sorption of gross gamma activity is also marginal whereas about 30% gross beta activity is sorbed. This is due to the sorption of ^{90}Sr and its daughter products on RA. The gross gamma activity was mainly due to ^{106}Ru - ^{106}Rh and ^{137}Cs in the CMPO loading effluent.

During the actinide partitioning of Purex HLW by extraction chromatographic technique using CMPO(13,14), trivalent actinide-lanthanide fractions are eluted in 0.04 M HNO₃. When this solution was contacted with biomass, most of the activities got sorbed. The sorption further improved, close to 100% on adjusting the pH to 2 as shown in Table 10. This confirms the ability of RA to sorb trivalent actinides and lanthanides from these type of wastes.

Data on RA sorption of alpha activities from a very low active Purex plant effluent (pH 11.5) containing very low alpha and beta-gamma activities are presented in Table 11. The effluent has been made alpha-free. When Am was spiked to this solution, only 75% of alpha was removed. The Am uptake went as high as >99% when pH was adjusted to 2. The experiment was conducted at 100 ml level. These data are also presented in Table 11. Even after increasing the contact time to 6 hrs., no appreciable change in the alpha activity of the effluent is noticed. These data are also presented in Table 11.

Sorption of alpha activities from plutonium spiked evaporator condensate samples has been tested as such and after adjusting the pH to 2 and 6, and the results are shown in Table 12. At 0.14 M HNO₃, 78% of the alpha activities has been sorbed with a marginal improvement at pH 2. Sorption went as high as 98% at pH 6. This result confirms that plutonium sorption is maximum at pH 6.

Experiments with Purex waste streams thus confirmed the results obtained with tracer studies. Whenever the waste streams were spiked with Pu or Am activity, these were allowed to settle for a few days before conducting equilibration experiments. The Pu activity in the carbonate solution used in the present experiments also remained constant as described above.

4. CONCLUSIONS

Biomass Rhizopus arrhizus (RA) appears effective for the removal of actinides and fission products from low level Purex plant waste/effluent solutions. Maximum sorption for uranium and plutonium is observed at 6-7 pH whereas for Am, Eu, Pm, Ce and Zr, the sorption is maximum at pH 2. Sorption for Ru and Cs are negligible. Sorbed nuclides are recoverable by elution with 1 M HNO₃ on once through basis. The biomass sorption technique can also prove useful in treating CMPO process waste streams containing trivalent actinides and lanthanides. Behaviour of Np has not been investigated. The method can be used for treating the condensates from the plant and the hold-up Delay Tank solution. The overall salt concentration in the matrix beyond 0.14 M seriously affects the metal uptake.

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6. REFERENCES

1. S.E.Shumate II and G.W.Strandberg, Comprehensive Biotechnology, Edit. C.W.Robinson and J.A.Howell, Pergamon Press, New York, Vol. 4, p. 235 (1985)
2. Y.P.Ting et.al, Biotechnology and Bioengineering, Vol. 37, p.445 (1991)
3. Gerald W. Strandberg et.al, Applied and Environmental Microbiology, Vol. 41, No.1,p.237 (1981)

4. M.Tsezos and B. Volesky, *Biotechnol. Bioeng.*, Vol. XXIV 23, p. 385 (1982)
5. M. Tsezos, *Biotechnol. Bioeng.*, Vol. XXVI, p. 973 (1984)
6. P.K.Khopkar et.al, *J. Inorg. Nucl. Chem.*, 36, 3819 (1974)
7. A.Ramanujam et.al, *Solvent Extraction and Ion Exchange*, 13(2) p. 301 (1995)
8. J.N.Mathur, *Polyhedron*, 10, 47 (1991)
9. Prescott S.C. and Dunn C.G. *Industrial Microbiology*, McGraw-Hill, New York. page No. 515 (1959)
10. Prema B.R., Bhattacharya P.K., *Appl. Microbiol.*, 10,524 (1962)
11. S.R.Udupa, M.S.Chadha, *Indian J. Biochem. & Biophys.* 15,328 (1978)
12. N.A. Salvi, S.S. Rane and S.R. Udupa, *Biotechnology Lett.* 17,285(1995)
13. A.Ramanujam, *Proc. Technical Committee Meeting, IAEA-TECDOC-783*, p. 63 (1995)
14. A.Ramanujam et.al, *Symp. Management of Radioactive and Toxic Wastes (SMART-95)*, BRNS, DAE, Bombay, March 20-21, 1995
15. Margaret E. Treen.Seers et.al, *Biotechnology and Bioeng.* Vol. XXVI. p. 1323 (1984)

Table 1.

Comparison of Sorbants for LLW Treatment

Feed Volume : 5.0 ml, Equilibration Time : 30 min.

Weight of Sorbant : 100 mg.

Sorbants	HNO ₃ /pH	Distribution Ratios			
		¹⁴⁴ Ce	¹²⁵ Sb	¹⁰⁶ Ru	¹³⁷ Cs
Dowex 50 X 4,	0.14 M	9727	14.3	15.3	38.9
(H ⁺ form)	pH 2	13358	11.0	18.6	31.4
Dowex 50 X 4,	0.14 M	1.2X10 ⁴	No uptake	11.7	35.3
(N ₂ H ₅ ⁺ form)	pH 2	> 10 ⁴	No uptake	17.3	38.8
Ammonium Molybdo-	0.14 M	21.1	3.95	No uptake	146
Phosphate (AMP)	pH 2	14.5	7.48	0.93	2.3X10 ⁴
<u>Rhizopus Arrhizus</u>	0.14 M	1362	2.17	0.95	1.34
(Biomass)	pH 2	6712	4.6	1.8	0.93

Table 2.

Sorption of Pu(IV) by Various Biomass

Feed volume = 2.0 ml

Weight of biomass = 25-30 mg, Mesh size = 30-50

Equilibration time = 15 min.

S.No.	Biomass	Dpu at	
		pH 4	pH 9
1.	<u>Rhizopus arrhizus</u>	3746	5415
2.	<u>Gibberella Fuiikoroi</u> NCIM 665 A-1	146	15
3.	<u>Gibberella Fuiikoroi</u> NCIM 665 A-2	149	46
4.	<u>Gibberella Saubinetti</u> NCIM 851	29	33

Table 3.

Kinetics of ^{241}Am Uptake by RA

Feed vol. : 2.0 ml, pH : 2
 Weight of RA : 18-30 mg, Mesh size : 30-50

Time (min.)	D_{Am}
5	4620
15	8180
30	8291
50	9304
70	11113
90	12638
*150	18474
*180	23540
*240	23698
*360	23410
*570	24743

* Expts. with 5.0 ml vol.

Table 4.

Uptake of U, Pu, Am and a Few Fission Products by RA

Feed volume : 2.0 ml,
Weight of RA : ~20 mg, Mesh size : 30-50
Contact time : 15 min.

Distribution Ratios (D)

pH	D _U	D _{Pu}	D _{Am}	D _{Eu}	D _{Pm}	D _{Ce}	D _{Zr}
2	414	204	8196	7113	9386	9448	1995
4	1049	3715	2731	2597	2641	2920	791
6	2725	7636	1638	1605	1714	2247	773
7	3071	9653	1381	1217	1486	1525	830
9	2973	5265	1147	1086	1573	1510	778
11	531	892	91	118	209	494	513

Table 5.

Influence of Various Anions on the Sorption of Pu by RA

Feed vol. : 2.0 ml, pH : 4,
Weight of RA : ~ 30 mg, Mesh size : 30-50
Contact time : 15 min.

(All anions were introduced as their sodium salts)

S.No.	medium (Conc., 0.1 M)	D _{Pu}
1.	---	3820
2.	SO ₄ ⁻⁻⁻	1241
3.	Cl ⁻	990
4.	CO ₃ ⁻⁻⁻	951
5.	NO ₃ ⁻	843
6.	CH ₃ COO ⁻	782
7.	C ₂ O ₄ ⁻⁻⁻	151

Table 6.

²⁴¹Am Uptake by RA in Presence of Sodium Nitrate

Feed volume : 2.0 ml, pH : 2,
Weight of RA : ~20 mg, Mesh size : 30-50
Contact time : 15 min.

NaNO₃ (M)	D_{Am}
N11	8155
0.02	8075
0.05	8102
0.07	8082
0.10	7600
0.14	7401
0.42	933
1.26	124
1.40	104

Table 7.

²⁴¹Am Uptake by RA in Presence of Nd

Feed volume : 2.0 ml, pH : 2
Weight of RA : ~20 mg, Mesh size : 30-50
Contact time : 15 min.

Nd Conc. (g/l)	D _{Am}
0	8063
0.02	3643
0.05	1911
0.10	668
0.25	53
0.50	34
1.00	20
1.50	15
2.00	12

Table 8.

Sorption of Radionuclides From Diluted Purex HLW by RA

Feed vol. : 5.0 ml, pH : 2
 Weight of RA : 104.7 mg, Mesh size : 30-50
 Time of contact : 15 min.

Constituents	Feed activity	Effluents activity	D	Sorption %
Gross alpha	41,760 CPM/ml	1,840 CPM/ml	1036	95.59
¹⁴⁴ Ce	5.649 mCi/l	0.004 mCi/l	6697	99.93
¹⁰⁶ Ru	1.313 mCi/l	1.269 mCi/l	1.66	3.35
¹³⁷ Cs	15.426 mCi/l	15.32 mCi/l	0.33	0.69
⁹⁵ Zr	0.049 mCi/l	ND	—	~100

Table 9.

**RA Sorption of Selected Fission Products from
Purex Waste Streams Encountered in
CMPO Extraction Chromatographic Experiments**

**Feed : Effluents from U-lean HAW loading on CAC Column,
adjusted to pH 2, Volume : 5.0 ml, pH: 2,
Weight of RA : 105.2 mg, Mesh size : 30-50
Contact time: 3 Hrs.**

Constituents	Feed activity	Effluent activity	% sorption
Gross alpha	ND	ND	---
Gross beta	91,38,460 CPM/ml	65,20,490 CPM/ml	28.65
Gross gamma	20,25,870 ..	19,05,020 ..	5.97
¹⁰⁶ Ru	0.32 mCi/l	0.31 mCi/l	3.13
¹³⁷ Cs	8.74 ..	8.57 ..	1.95

Table 10.

**RA Sorption of Trivalent Actinides and Lanthanides
From Purex Waste Streams Encountered in
CMPO Extraction Chromatographic Experiments**

Feed : 20 ml from actinide-lanthanide eluate,
Weight of RA : 200 mg., Mesh size : 30-50,
Contact time : 3 Hrs.

HNO ₃ Acidity/pH	Constituents	Feed activity	Effluents activity	Sorption %
0.04 M	gross α (CPM/ml)	26130	260	99.0
	gross β ..	4819620	65130	98.7
	gross γ ..	246905	7040	97.2
	¹⁴⁴ Ce (mCi/l)	0.73	0.009	98.8
	¹⁵⁴ Eu ..	0.11	0.001	99.1
pH 2	gross α (CPM/ml)	28630	230	99.2
	gross β ..	4566840	56600	98.8
	gross γ ..	245310	4810	98.0
	¹⁴⁴ Ce (mCi/l)	0.72	0.008	98.9
	¹⁵⁴ Eu ..	0.10	ND	~100.0

Table 11.

RA Sorption of Alpha Activities
From Low Level Purex Plant Effluents

Feed : 100 ml of Hold-up-cum-Delay Tank Sample,
Contact time : 3 Hrs. & 6 Hrs.,
Weight of RA : 500 mg, Mesh size : 30-50

pH	Alpha activity (CPM/ml)		Sorption %
	Feed	Effluent	
*11.55	8	ND (ND)	~100 (100)
#11.55	2,26,080	58,160 (56,460)	74.3 (75.0)
@2	44,160	440 (260)	99.0 (99.4)

Data in paranthesis are for 6 hours' contact.

* Sample as it is

Sample after Am spiking

@ Sample after Am spiking and pH adjusting to 2

Table 12.

**Sorption of Alpha Activities from Plutonium Spiked
Condensate Sample by RA**

Feed Volume : 100 ml, Contact time : 3 Hrs.,

Weight of RA : 100 mg, Mesh size : 30-50

HNO ₃ / pH	Alpha activity (CPM/ml)		Sorption (%)
	Feed	Effluent	
0.14 M	65,320	14,380	77.99
pH 2	64,810	12,860	80.16
pH 6	63,540	1,160	98.17

